

Rethinking science communication models in practice

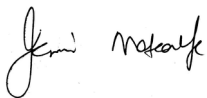
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Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person, except where due reference has been made in the text. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature, firstly at the University of Queensland (6/10/2011-31/5/2016), and then at the Australian National University (commenced on 24/06/2016). It does not include a substantial part of work that has been submitted to qualify for the award of any other higher degree or diploma in any other university or tertiary institution.

A handwritten signature in black ink, appearing to read 'Jenni Metcalfe', with a stylized, cursive script.

Jennifer Ellen Metcalfe

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This is a very long list of acknowledgements, and in writing this I realise that when you do a PhD part time over many years involving three universities that it's a journey. There are many people who come in and out of your life and who make a difference. There are deaths and births; there is despair and joy. There are challenges you don't think you'll ever surmount and then opportunities that open big fat doors. And all of those moments involve other people. I could not have completed this thesis without those people.

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Abstract

Scholars have variously described and theorised different models of science communication over the past 20 years. This has paralleled an increasing emphasis by science communicators and policy makers for more deliberative public engagement in science.

The problem I address in this thesis is: how well does the practice of science communication, especially when the science is publicly controversial, reflect the theorised models of science communication? This addresses a significant gap in scholarship as to date there has been little comparison of the science communication models against practice.

My literature review synthesises the breadth and depth of how scholars have theorised about the three main science communication models (deficit, dialogue and participation) to produce a comprehensive framework of model characteristics. I then compare the framework of theorised characteristics of the three models with (a) 415 science engagement activities recorded in a 2012 Australian audit; (b) oppositional climate science blogs www.skepticalscience.com and www.joannenova.com; and (c) a seven-year case study: the Australian Climate Champion Program, where scientists and farmers jointly addressed the problem of climate risk.

The data collected for the practice case studies were compared against the literature-based framework of selected characteristics for the theorised science communication models. Data were investigated through thematic content analysis, discourse analysis and descriptive statistical analysis.

I found that for all practice examples, most science engagement activities had objectives and characteristics that reflected a mix of those theorised for deficit, dialogue and sometimes participatory activities. The empirical analysis of practice in this thesis

confirmed that the three models do coexist in practice, but also indicated why and how they coexist. This coexistence of models in practice appears to be not merely an unintentional lucky accident but a necessity for science communication activities to achieve their objectives, especially when the science is controversial. The models proposed by scholars do not appear to take into account the extensive nature and mix of objectives for initiating or participating in science communication activities.

The importance of developing trusted relationships between participants for achieving the desired outcomes of all the theorised models of science communication was demonstrated by the Climate Champion Program case study. Participants in this program, which investigated climate risk, were much more open with each other, including when acknowledging uncertainties. Scientists changed the science they did, the shape of their research outputs and how they communicated about those outputs as a result of their involvement in the program. Trusted relationships developed through participation appear to make linear communication more viable, a finding which questions how many scholars have perceived the evolutionary nature of science communication models from deficit to more participatory forms of engagement.

This research improves understanding of how theorised science communication models might be further shaped to better reflect and even influence practice. I propose the new nexus model for science communication and describe how this can be implemented within the practical contexts of considering the objectives for engagement, who is involved in the engagement activity, and how positive relationships can be fostered amongst those participating.

Key words: science communication, science communication models, public engagement, climate change

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Glossary of common acronyms used

ANU	Australian National University
ASC	Australian Science Communicators
BSE	Bovine Spongiform Encephalopathy, or mad cow disease
CCP	Climate Champion Program
CGIAR	Consultative Group on International Agricultural Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GM	Genetically Modified
GRDC	Grains Research & Development Corporation
MCV	Managing Climate Variability
NGO	Non-Government Organisation
OECD	Organisation for Economic Cooperation and Development
PCST	Public Communication of Science and Technology
PUS	Public Understanding of Science
RDC	Research and Development Corporation
UK	United Kingdom
USA	United States of America

1. Introduction

1.1 Background to thesis

This thesis arose in response to the disconnect I perceived between science communication theory and practice. Since the mid 1980s there has been a growing scholarly literature about science communication, but I was unsure if it reflected science communication in practice or if it could inform practice to make it more effective.

My original purpose was to compare the theories about science communication as found in the literature with the practice of science communication as shown in case studies. I wanted to see if there were connections between the two, and if science communication practice could potentially be improved by paying more attention to the predictions and explanations of theories and scholarly research. This purpose reflected my 30-year background as a science communication practitioner, which followed careers in science and journalism. My first role in science communication was working as a communication manager for Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). After six years at CSIRO, in 1995 I started my own science communication business, Econnect Communication. My continued work as a science communication practitioner means I have experienced first-hand the relative effectiveness of various practical science communication activities. This includes working on projects focussed on climate, biodiversity, ecological, agricultural and natural resources sciences. Scientific findings in these arenas are often publicly contested, for example climate change findings, meaning science communication is even more complex and challenging. I was interested to find out if theorised science communication might help science communication practitioners wrestling with such challenges.

On the flipside, I also wondered if the scholarly theories and models about science communication could be further developed by reflecting on practice. I first heard about the theories of science communication, including the various models of science communication, through my involvement with the International Network for the Public Communication of Science and Technology (PCST Network) conferences. I attended my first conference in Montreal, Canada in 1994 and I have attended every biennial conference since then. The PCST Network aims to bring science communication practitioners and scholars together for mutual benefit. I have always felt like I straddle both camps, although with a pronounced lean towards practice, and this means I have an on-going interest in the nexus between the two.

When I started to review the literature on science communication theories, I found a focus on science communication models, which present representations of reality, rather than theories. Scholarly research about science communication appears mostly to borrow from theoretical perspectives from other fields or disciplines such as sociology, social science, psychology, science and technology studies, media studies, formal education and communication more broadly (Gascoigne et al., 2010; Stocklmayer & Rennie, 2017; Trench & Bucchi, 2010). As a consequence of this, I decided to focus on the science communication models prevalent in the literature rather than any broader considerations of theoretical science communication.

My aim then became to compare the science communication models described in the literature with practice examples. My review of the literature uncovered only three examples (discussed later in this chapter) of where science communication models had been empirically compared with science communication practice, and two of these studies focussed on the perceptions of science communicators about their practice rather than the practices themselves. All of these studies provided interesting insights into the

real or perceived practice of science communicators, but they did not explore further the implications for more theoretical considerations of science communication.

This thesis includes an extensive review of the literature on science communication models in order to set the scene and provide the framework for examining practice examples. The literature review uncovers a rich mix of objectives and motivations which various scholars have theorised as characteristic or predictive of the postulated science communication models. It is the theorisation about models that this thesis focuses on. The collation and synthesis of this breadth of theorisation about science communication models into one place has never been done before and offers a starting point for the analyses of practice that follow.

I was also interested to discover that the scholarly literature often situated its theorisation of science communication models with emerging publicly controversial science issues. This led me to a new thesis question about how the theorised science communication models were characterised in science communication practices on controversial issues compared with non-controversial issues. I wanted to find out what that meant for the practice of science communication, and for further development of the models.

My first analysis comparing the theorised models with practice uses nation-wide data collected during an Australian audit of science engagement activities in 2012. This large data set of quantitative and qualitative responses had a wide mix of science communication activities, making it ideal for comparing the theorised characteristics of science communication models with what was happening in practice. Interestingly, my analysis of the data indicated that all relevant qualitative and quantitative responses for each activity needed to be studied in order to get a clear picture of how theorised science communication models were characterised in the activity. Analysing just one

response was not enough for understanding how science communication models were characterised within a specific activity.

I further used the Australian audit data to identify and compare those science engagement activities that were controversial with those that were non-controversial. Publicly controversial scientific issues in Australia include climate change, and to a lesser extent other environmental issues, nanotechnology genetically modified organisms, stem cell research, and biotechnology (Ankeny & Dodds, 2008; Harwood & Schibeci, 2008; Hindmarsh & Du Plessis, 2008). Given the dominance of climate change in Australian political and public arguments about science, my two next case studies focused on science communication around this issue.

Firstly, I investigated oppositional blogs on climate change science. I chose blogs as representative of the social media hype of the past decade, and its potential for more deliberative engagement of publics in controversial scientific issues. Some researchers see the interactive nature of science blogs as being “an expression of this new [dialogue / participation] public communication of science” (Colson, 2011, p. 892). Indeed, much has been made of the potential of social media, like the blogosphere, for publics to have more of a voice in political issues and the media agenda (Jaspal et al., 2012; Jenkins, 2006; Marres, 2007). Therefore, I thought it would be productive to compare example social media activities on controversial science with the theorised characteristics of more deliberative science communication models. I specifically chose to analyse the commenters to such blogs rather than the bloggers to find out how publics were engaging with each other and the science, and how that engagement reflected the characteristics of the theorised science communication models. There has been very little research on commenters to science blogs (Jarreau & Porter, 2018) compared to the

research that had been done on commenters to political blogs, so I thought this would also form an interesting and relevant comparison of engagement on polarised topics.

Secondly, I chose a long-term participatory science communication program involving farmers and scientists in climate science, known as the Climate Champion Program, to examine how that program appeared to reflect the theorised science communication models. While there has been considerable research on dialogue and participatory science communication activities, much of this has focussed on short-term and one-off events involving representatives of mass publics. For example, consensus conferences on controversial topics like food biotechnology (Einsiedel et al., 2001) or nanotechnology (Kleinman et al., 2011) or citizens juries, such as United Kingdom's (UK) NanoJury examining nanotechnology and its implications (Bickerstaff et al., 2010). The Climate Champion Program was a long-term initiative with a focus on a specific issue (climate risk for farming) and involving those especially affected by that issue (farmers from around Australia) with scientists. I devised and initiated the program after conducting communication research for the Australian Bureau of Meteorology in 2008 which analysed farmers' needs from seasonal forecasts and asked for feedback on some of the Australian Bureau of Meteorology's draft seasonal forecasting products. This study resulted in significant changes to these products as well as the recommendation for the Bureau to: "work with target users, in a participatory style of science communication" (Land and Water Australia, 2008, p. 25) to jointly develop clearer explanations and understanding of climate risk. I was particularly interested to compare the characteristics of this program with the theorised science communication models to see how well they reflected the theorised participatory model.

Each of my empirical analyses of practice point to gaps or flaws in the theorised models of science communication and ways the models could be better theorised to

more accurately describe and predict practice. In my concluding chapter, I postulate a new ‘nexus model’ of science communication which is based on both the theorised science communication models and my empirical findings from analysing practice. This new model can be explored further theoretically, tested against practice, and also holds direct implications for practice.

1.2 Academic context

1.2.1 Growing scholarly literature base on science communication models

Since the mid 1980s there has been a growing literature base about science communication. To a large extent this has followed the expansion of science communication institutions and practice across continents to be a global force (Trench et al., 2014). The expanding science communication research scene often appears to be aimed at improving our understanding of the best ways to communicate complex information to be people not directly involved in science (Priest, 2010).

Much of the expansion in scholarly science communication research has focussed on models. Trench and Bucchi (2010, p. 2) claim that the “near-20 years of discussion of models of science communication – since the naming of the ‘deficit model’ – is the most solid thread of theoretical work in this field”. A bibliometric analysis (INSCICO, *Science Communication Research Field Analysis, Policy Perspectives for Germany in the Global Context*, 2017, Unpublished report) of all research papers published in the three science communication journals—*Public Understanding of Science (PUS)*, *Science Communication (SCX)* and *Journal of Science Communication (JCOM)*—from when *Science Communication* started in 1979 until the end of 2016 found that 41 per cent of all research articles made at least some reference to science communication models. Many of these papers contributed to the

areas of science literacy and the public understanding of science. At least 12 per cent explicitly focussed on science communication models. Likewise, an analysis of science communication journal articles published by Australian scholars between 2001 and 2011 found that papers on science communication models had more than doubled from 22 per cent of all papers to 48 per cent over that time period (Metcalf & Gascoigne, 2012).

A dominant focus of the academic discussion theorising about science communication models attempts to describe the relationships that exists between scientists and publics in the communication process, including the objectives of scientists or science communicators for engaging with publics (Bucchi, 2004; 2014; Callon, 1999; Lewenstein, 2005; Rowe & Frewer, 2005; Trench & Junker, 2001). According to Brossard and Lewenstein (2010) these models are “frameworks for understanding what the ‘problem’ is, how to measure the problem, and how to address the problem” (p. 13); the ‘problem’ being the public’s understanding of and relationship with science. Alternatively, there is the conceived problem of scientists’ lack of understanding or relationship with publics. Regardless, both these conceptions generate ‘blame’ models. Publics may be being blamed for not understanding and appreciating science, and scientists may be blamed for not understanding publics, trying to have positive relationships with publics or attempting to engage with them. In some cases, both scientists and publics are blamed for not engaging with each other and others to try and more deliberately solve important societal issues. In other words, instead of the models being helpful for explaining and informing science communication practice they can be used to criticise the efforts of practitioners.

The focus on models in the literature is particularly worth exploring given that science communication is still developing as an academic field, with a paucity of

theoretical approaches (Trench & Bucchi, 2010). This thesis seeks to compare the theorised science communication models against practice in order to empirically test and further develop them.

1.2.2 Theories and models and the ‘theorised science communication models’

At this point, it's important that I discuss the distinctions between theory and models, as used in this thesis. A theory is a generalised conclusion or explanation about something, which results from analysis of evidence. In the introduction to their book on 'Integrated Approaches to Communication Theory and Research', Stacks and Salwen (2009) say that a communication theory "...organizes and refines our ideas like a map for explaining unexplored territories" (p. 4). In this way, they argue that theoretically driven research involves testing and then building on the knowledge of "previous explorers". In the context of this definition of theory being built on empirical evidence, the science communication models in the literature are not theories, however various scholars have theorised about their characteristics, although the evidence for this theorisation is not often clear. Craig (1993) says communication theory evolves from our intellectual and cultural history, and therefore is reflexive. Being reflexive, it can change and reinforce communication practice and thinking. The theorisation about science communication models in the literature appears to be particularly reflective of the UK and United States of America (USA) intellectual and cultural science communication traditions and history. As is discussed in the literature review (Chapter 2), the development of the science communication models was very much shaped by the controversies and policy developments that happened in both these countries since the 1980s.

A model, in comparison to a theory, is a verbal or visual representation of a concept, which aims to represent and simplify reality. A model usually does not attempt to explain or predict reality. The science communication models discussed in this thesis,

and particularly in the Chapter 2 literature review, can be visualised, but whether they represent and simplify reality has not been fully explored or tested. This thesis compares the widely theorised characteristics of the dominant science communication models against practice. For example, the theorised objectives predicted for each model are tested against whether these objectives are evident in practice.

However, models can be used to form a theory; models can be used to test theories; and models can be used to represent theory or an aspect of theory and make it more concrete. The relationship between research, models and practice can be complex and difficult to understand in science communication. Trench (2012) provides a clue to how science communication models may be relevant to practice when he says that science communication models construct the relations “between participants in a communication process and provide the basis for the strategies adopted in communication acts or initiatives” (p. 2). The models of science communication that are described in the literature represent how scholars argue science has been, is being or should be communicated. They are ‘theorised’ science communication models, which are empirically compared with practice in this thesis. Such comparisons are useful for validating, developing or replacing the scholarly theories centred on science communication models. This process should also lead to further refinement or even replacement of the science communication models.

The multimodal approaches to science communication theory presented by scholars largely emerged chronologically and showed a mix of objectives. Bauer, Allum, and Miller (2007) argued that the three dominant models they presented (science literacy, public understanding of science, and science in society) still powerfully informed science communication research. The science literacy model assumes that publics need to be knowledgeable about science, and, as previously discussed, they are

blamed if they are not literate in science. This model of science communication is commonly referred to as the ‘deficit model’, where scientists provide information to fill a deficit of knowledge by publics. The public understanding of science model promotes dialogue between scientists and publics so that publics can better understand the science. This model is commonly referred to as the ‘dialogue model’, where there is a two-way conversation between scientists and publics. Scientists seek to understand the perceptions, concerns and needs of publics, and recognise that they may also have knowledge useful to the scientific process. With this model, scientists may be blamed for not properly understanding publics and communicating with them. They may also be blamed for not considering various publics’ knowledge in their research. In the science in society model, science is seen as one of a number of sources of knowledge and expertise in solving societal problems, along with other equally valid sources. This model is commonly referred to in the literature as the ‘participatory model’ where scientists engage with various publics on a more or less equal basis. Scientists and various publics may be blamed for not participating effectively with each other to create positive societal change. As section 2.5 of Chapter 2 further discusses, the theorised characteristics of the models sometimes appear to apportion blame rather than being based on empirical evidence. This sense of blame may be another factor disconnecting science communication scholars and practitioners. Miller (2008) noted that science communication practitioners may perceive social scientists to be dismissive of science communication practice. He previously also noted that the scholar-practitioner divide was exacerbated by the scholarly attention given to the ‘science in society’ model of science communication that grew out of published research critiques of practical science communication activities (Miller, 2003). It is within this context that this thesis asks whether the theorised science communication models empirically explain the reality of

practice. It also questions whether theorised science communication models can inform practice so science communicators can be more effective at achieving their objectives, especially with controversial science.

1.2.3 Comparing theorised models of science communication with practice

Theorised science communication models attempt to capture a past, present or possible reality; but the assumptions of these models have not been widely tested with reference to the practice of science communication (Salmon et al., 2015). One notable exception to this was Brossard and Lewenstein's (2010) analysis of the Human Genome Project's Ethical, Legal and Social Implications outreach where they assessed case studies of practice against four science communication models: deficit, contextual (where scientists consult the public to understand how people respond to information and thus communicate better with them), lay expertise (where scientists seek to understand and value lay knowledge alongside scientific), and public engagement (where citizen views and knowledge are integrated into policy debates). They found in practice that projects took a pragmatic approach and adopted parts of each science communication model according to the different contexts and needs of various publics. Jensen and Holliman (2015) investigated practices and discourses of UK science engagement practitioners (scientists at various stages of their careers who engage with the public) about their own experiences and compared these to Irwin's (2008) three levels of thinking. Irwin's first level thinking is similar to the deficit model (where scientists convey information to publics using one-way communication methods); the second level thinking is similar to the dialogue model (where scientists engage with publics through a two-way conversation); and the third level of thinking goes beyond the participatory model (where scientists engage directly with publics on a more equal basis) towards a more critical engagement of publics in science and its institutions. Jensen and Holliman

(2015) found the experiences of practitioners to be firmly rooted in deficit-style communication, with some limited discourse and acceptance of dialogue methods. There appeared to be very little experience of second or third order thinking activities. However, this study did not examine specific science communication practices but rather the perceptions of the science communication practitioners. In another study, Laura Bartock (2015) for her Master of Science thesis at the State University of New York compared the three science communication models (deficit, dialogue and participation) with USA science communicators' perceptions of their roles and responsibilities, audience/s and any ethical considerations. Her research focused on science communication practitioners working on projects at Long Term Ecological Research (LTER) sites, which are funded through the National Science Foundation. After analysing the semi-structured interviews, she concluded that the dialogue model dominated their practices, and that many practitioners were aware of the shortcomings of the deficit model and the difficulties of applying more participatory science communication approaches. Bartock's (2015) results showing a dominance of dialogue experience rather than deficit likely differ from Jensen and Holliman's (2015) because she targeted those who have a specific role in science communication rather than scientists who occasionally do science communication. These three studies demonstrate that a few scholars have begun to examine the nexus between theorised science communication models and practice, but only the first study (Brossard & Lewenstein, 2010) empirically examined and compared the actual practices of science communicators; the last two studies focus on the perceptions of science communicators rather than their actual practices. My thesis directly analyses science communication practice and compares these practices to the predicted characteristics of science communication models.

1.2.4 Relationships between science communication scholars and practitioners

The breadth of activity under the science communication umbrella is immense.

Featherstone et al. (2014) argue that the diversity of the field of science communication, which includes a range of different practitioners, as well as scholars with a diversity of disciplinary orientations, creates a diversity of motivations with both benefits and challenges for collaboration in the field. While Featherstone et al. (2014) argue that the field is motivated by the central idea, that “everyone involved in science communication wants it to be as good as possible” (p. 12), it is also important to recognise that the differing cultures of academics and practitioners create tensions (see, for example, Miller, 2003; Miller, 2008). Tensions are created due to the differing pace of activities, with practice moving quicker than academia (Featherstone et al., 2014); scholars’ attitudes towards the efficacy of practice and practitioners toward the relevance of research (Miller, 2008; Han & Stenhouse, 2015); and the lack of productive spaces where scholars and practitioners can respond effectively to each other (Miller, 2003). Their priorities are also different. For example, project evaluation research, a central focus of collaboration between scholars and practitioners within the field, often focusses on short-term and localised practice projects, rather than developing generalised knowledge, which is what usually drives scholarly research (Featherstone et al. 2014).

A 2011 survey of science communication practitioners in Australia (Metcalf & Gascoigne, 2012) found that those only involved in science communication practice (as compared to research *and* practice) were far more likely to obtain advice from colleagues inside or outside their organisation than to refer to published research. In contrast, however, Miller (2008) conducted a survey of science communication practitioners attending a British Association for the Advancement of Science meeting and found that 40 per cent of survey respondents were not reading the research in the

field, which implies that the majority were reading the research, or at least did not say they were not. Regardless, Salmon et al., (2015) suggest that the academic literature can only be a starting point for conversations between researchers and practitioners rather than an end in itself.

A study was conducted for the German government during 2016-17 that included interviews with 34 science communication experts around the world about their views on science communication research (INSCICO, 2017). Some of the experts interviewed considered the relationships between practitioners and scholars of science communication to be an important challenge for all researchers to address. As one expert said;

We don't have a calling card for science communication. We can be happy with our tacit communities but if we want to influence policy makers, we need to open the dialogue and build awareness of a field of scholarship developed over many years versus a group of individuals with our own contacts.

Other experts did not think it was their role to communicate with practitioners, and some pointed out that not all research had practical implications. A few experts argued that science communication scholars were already doing a good job of linking research with practice. The experts made three suggestions for strengthening the links between science communication research with practice. These interestingly corresponded to the three dominant models of science communication: publications on various forums to explain the research simply (deficit model), planned interactions at conferences and other local forums (dialogue model), and involving practitioners directly in research (participatory model).

The challenges perceived between scholars and practitioners, and between research and practice were drivers of this thesis. While this thesis does not aim to resolve these challenges, it does seek to explore the applications of theorised models of

science communication to practice. Such theoretical and empirical investigations may determine the relevance of such theorised models to practitioners as well as help shape the further theoretical development of the models.

This thesis is fundamentally about science communication, and as such it is important to explain what I mean by the term ‘science communication’ and to describe who the actors are within this community.

1.3 Defining science communication and the actors involved

In 2011, an online survey was conducted with Australian Science Communicators (Metcalf & Gascoigne, 2012) where almost half (30) of the 65 participants also claimed to be involved in both communication research and practice. More recently, an informal poll was conducted at a recent PCST Network conference in New Zealand (April 2018). Participants in one of the sessions were asked to raise their hands if they were (a) a science communication scholar only; (b) a science communication practitioner only; or (c) both. By far the majority of participants claimed to wear both hats. There appears to be a growing trend of practitioners doing research and scholars engaging in practice, which is not examined in this thesis but is another topic worthy of research.

But what is ‘science communication’? How does it compare with the increasingly popular use of the phrase ‘science engagement’? And what is a science communicator compared to a science communication scholar?

1.3.1 Defining science communication

The theorised science communication models include two main actors—scientists and the public, and the relationships between them. Some also discuss the role of policy makers and professional science communicators. On its “About This Journal” webpage,

the journal, *Science Communication* (SAGE Publishing, 2018, para. 2), states that it:

...unites international scholarly exploration of three broad but interrelated topics: Communication within research communities - Communication of scientific and technical information to the public - Science and Technology communications policy. Science is broadly defined within the context of *Science Communication* to include social science, engineering, medical knowledge, as well as the physical and natural sciences.”

The first topic mentioned here, “communication within research communities”, is more about ‘scientific communication’, which I argue differs from ‘science communication’ in that it involves scientists communicating among themselves rather than with the public. In a paper I co-authored (Gascoigne, et al., 2010, p. 4) we defined science communication as something that: “deals with the diffusion, propagation and appropriation of scientific knowledge in different contexts, for different purposes, with different effects (intended or unintended)”. This definition does not exclude communication amongst scientists, something that Trench and Bucchi (2010, p. 1) noted was an issue when clarifying the field of science communication:

...it concerns the communication between communities of scientists, interest groups, policy-makers and various publics. But, on further reflection, we have to consider whether science communication also includes communication between and within various scientific institutions and communities of scientists.

For the purposes of my thesis, like some other scholars (e.g. Burns et al., 2003; Mullahy, 2004), I am defining ‘science communication’ as being the communication between scientists or science communicators and those without formal scientific expertise (e.g. laypersons, publics), rather than as being between scientists. As per the *Science Communication* quote above, those topics include all the sciences, from the natural sciences to social sciences.

Interestingly, in their 2017 publication, *Communicating Science Effectively: A Research Agenda*, the USA National Academies of Sciences, Engineering, and Medicine define science communication:

...as the exchange of information and viewpoints about science to achieve a goal or objective such as fostering greater understanding of science and scientific methods or gaining greater insight into diverse public views and concerns about the science related to a contentious issue (p. 2).

This instrumental definition for science communication focuses on objectives and hence presumed outcomes, something that is also prevalent in scholars' theorising about science communication models (see Chapter 2). It also focuses on publicly controversial science by mentioning 'viewpoints', 'diverse public views and concerns', and 'contentious issues'. This concern about controversial science in the last few decades has led government policy makers, scholars and practitioners to talk more about science 'engagement' rather than 'communication' (Jensen & Holliman, 2015).

1.3.2 The move towards public 'engagement' in science

The focus on 'engagement' rather than 'communication' is seen in projects like those funded under the European Science in Society and Science with and for Society Programs, including the Engage2020 program (<http://engage2020.eu/>, retrieved 18 May 2019). Bultitude (2011) argues that this change in terminology may have arisen because some practitioners and policy makers perceived science communication to be about just one-way communication of knowledge rather than two-way 'engagement' where scientists interact and work together with the public. Governments of western democracies also began to talk more about need for increased public 'engagement' in science (Srinivas, 2017; Davies et al., 2009).

In the UK, the House of Lords' Science and Society report in 2000 (UK House of Lords Select Committee on Science and Technology, 2000) led the way for a series of other reports that called for and articulated the need for greater public *engagement* in science (Joly & Kaufmann, 2008). When the science is controversial, such as is the case for climate change or genetic modification, public engagement is perceived to be needed to critically review research, solve problems or to support behaviour and policy changes (Few et al., 2007; Höppner, 2009; Marquart-Pyatt et al., 2011). But like science communication, 'science engagement' is also difficult to define.

Irwin (2014) says "Like beauty, [the definition of] *engagement* can lie in the eye of the beholder" (p. 166) and this seems to be the case when reviewing the literature definitions of public engagement in science; definitions vary from those that are broad and inclusive of all science communication to those that are much more narrow and specific about the type of or objective for activities. Broad and inclusive definitions include:

- "any scientific communication that engages an audience outside academia" (Poliakoff & Webb, 2007, p. 244);
- "a form of two-way communication between the public and those who have knowledge of, or power over, the particular issues at stake" (Joly & Kaufman, 2008, p. 226); and
- "communicative action to establish a dialogue between science and various publics" (Bauer & Jensen, 2011, p. 4)

Narrower and more specific definitions of public engagement include:

- "the activities where scientists meet with publics and have a discussion which shapes the practice of science" (Benneworth, 2009, p. 2); and

- “interactive and iterative processes of deliberation among citizens and between citizens and government officials with the purpose of contributing meaningfully to specific public policy decisions in a transparent and accountable way”
(Philips & Orsini, 2002, p. 3);

Public ‘engagement’ in science is used to describe a variety of science communication activities from public lectures, to community consultation to deliberative consensus conferences (Bauer & Jensen, 2011; Dudo, 2012; Powell & Colin, 2009). I argue ‘public engagement’ in science has been used by various policy makers, scientists, science communication practitioners and scholars to provide a more acceptable and progressive image of ‘science communication’. However, like Burns, O’Connor, and Stocklmayer (2003), I define science communication in its broadest sense to include all these definitions and forms of ‘science engagement’.

1.3.3 Science communication practitioners and scholars

I am often asked what I do, and if I reply that I am a ‘science communicator’, then people are confused. They understand what a teacher is, what a journalist is, and what a scientist is but they don’t know what a science communicator is. I generally explain by saying something more detailed like, ‘I help scientists to communicate their complex and technical research with ordinary everyday people, so they can more easily understand it and make better decisions’. But I am conscious that I am only telling part of my science communication story. I also help people like farmers to interact with scientists; they give scientists feedback about their research direction and intended products. I research what people like urban water users want to know about the science of water conservation. I work with scientists and research managers to develop policy recommendations based on the best available science, for example on factors affecting

the health of the Great Barrier Reef. I research and produce displays and interactive exhibits for environment visitor centres. A professional science communicator can be and do many things.

Most scientists also do ‘science communication’ and may refer to themselves as science communicators. Burns et al. (2003) point to the lack of clarity in the meaning of science communication, and what a science communicator does. They postulate that it is not merely an offshoot from the field of ‘communication’. Instead they define science communication as “the use of appropriate skills, media, activities, and dialogue to produce one or more of the following responses to science...awareness...enjoyment...interest...opinions.... [and] understanding of science” (p. 191). This definition attempts to explain the breadth and diversity of roles that a science communicator may be involved in.

At the start of this section I highlighted that many of those involved in science communication see themselves as both a practitioner and a scholar. Modern science communication exists as both a field of scholarly research and a practice, similar to other multidisciplinary fields like journalism and public health (Gascoigne et al., 2010). The scholarship of science communication “draws its tools and concepts from sociology, psychology, media studies, statistics and other areas, and has an interdisciplinary approach in common with modern social sciences” (Gascoigne et al., 2010, p. 4). But the boundary between research and practice is often blurred. McKenzie (2014) in her PhD thesis says: “A useful distinction can be made between practitioners and researchers by proposing that there are those who do science communication (i.e. science communicators), and those who study what science communicators do.” In keeping with this distinction, science communicators can be defined broadly by their roles—“the activities of professional [science] communicators (journalists, public

information officers, scientists themselves)" (Treise & Weigold, 2002, p. 311). In this sense, anyone involved in communicating science to the public can be defined as a science communicator.

1.3.4 Understanding who the public is

But who are the 'public? Many science communicators and scientists conceive of an imagined public, who are often a mass audience and referred to as the 'general public'. The public are often perceived and presented in the media, as acting as a single social entity (Warner, 2002), yet Mohr et al. (2013, p. i) encourages scholars and practitioners to not see the 'public' as singular and instead to talk about 'publics' in the plural, as "plural, dynamic and capable mobilising around shared interests". Mohr et al. (2013) also describes 'latent publics', whose voices have not yet been articulated or made visible in societal discussions of science. This is in comparison with those visible and interested publics (Miller, 2010) regularly participating in science activities and discussions. They are also in contrast with those publics responding to opinion polls or engaged in activism about science activities. Latent publics may be mobilised to engage with science through specific activities including lectures, festivals and media articles. Through the process of science communication, publics may form, re-form or be transformed by the process.

Marres (2005) describes the process through which controversial science issues can create new issues-based publics. Other scholars (Featherstone et al., 2009) looked at whether 'the public' can be segmented into different groups based on their attitudes to a specific publicly-contested science issue, like climate change. They found that publics could be segmented, but that this could change over time with specific interventions. For example, publics could be segmented based on the degree to which they recognise and accept a specific scientific stance about an issue (e.g. anthropogenic causes of

climate change). Communication strategies could then specifically target those with an early acceptance of the consensus scientific view with the aim of moving them towards active engagement in the issue (e.g. action to mitigate climate change). Other communication strategies would use different tactics to engage those less aware and / or accepting of the consensus scientific view. Braun and Schultz (2009) present a typology of four publics participating in science communication about genetic testing. Their typology was based on how each public was constructed through the participatory process: the general public (anonymous people consulted through opinion polls and surveys), the pure public (those without strong opinions or political agendas engaged through citizen juries and consensus conferences), the affected public (those directly affected by the science, e.g. they have a genetic disease) and the partisan public (those with strong opinions and agendas). It is clear with these examples that controversial science plays a role in defining the ‘publics’ who emerge in the science communication process. The growing relationship between science and society can also create ‘scientific citizens’, a process which can result in a “growing socialization of science, and an advancing ‘laboratization’ of society” (Elam & Bertilsson, 2003, p. 246). Such scientific citizens are likely to have a natural interest in and desire to be engaged in science, whether it is controversial or not. My thesis recognises that there are likely multiple publics for science communication, and that in practice these publics may be engaged in science for a multiplicity of reasons.

In this thesis I refer to multiple ‘publics’, who include groups like urban communities, rural communities, policy makers, industry representatives, business people, farmers and so on. Such publics may have formed through a common interest in a topic, a specific issue, or through a participatory science communication program. For example, Chapter 5 looks at the participation of farmers with scientists.

1.4 Controversial science

It is apparent from a review of the literature (see Chapter 2) that the more controversial science becomes with publics, the more that various actors call for different models of engagement. This is often because traditional means of science communication are perceived to fail in practice (Irwin, 2008; 2014). Following McMullin (1987), I define ‘scientific controversy’ as a “publicly conducted and persistently maintained dispute” over a matter of belief where “each side of the controversy claims the authority of ‘science’ for their view” (p. 51). This definition means that a scientific controversy endures publicly over a significant period of time. Given the role of controversy in shaping the theoretical development of science communication models, it is important that I explore the notion of controversy further in this thesis. Therefore, this thesis compares two practical examples focussed on climate change science with the theorised science communication models.

1.4.1 Climate Change as an example of a controversial science issue

For those involved in communication about climate science, there is a perceived need to overturn the influential views of climate deniers and gain publics’ support for peer-reviewed climate science (e.g. Cook, 2014). It is hoped that such support will in turn lead to support for policy and behaviour changes that are thought to be critical for mitigating or adapting to climate change.

Climate change is a controversial public issue in Australia, as it is in USA and to a lesser extent, the UK and other western democracies. Despite Australia being warned of climate change threats by scientists some 30 years ago, Australia is ranked among the worst developed countries for climate action (Slezak, 2016). Many players and agendas compete for attention in controversial issues such as climate change. Such issues

generate increased public interest and engagement in shaping the debate around the science and the politics when the existing institutions such as science organisations, governments, advocacy groups and the media fail to resolve matters (Marres, 2007). Most experts argue that the success of climate change policies, such as international treaties to reduce emissions, will depend on broad public support (Prikken, Burrall & Katyirtzi, 2011; Marquart et al., 2011; Swain, 2012). Lemonick (2010) argues that “it will take massive changes in agriculture, energy production and more to avert a potential disaster [from climate change]” (p. 80). Some scholars argue such engagement is best done through more deliberative communication if we are to meet the challenges of climate change (Niemeyer, 2013).

However, despite the huge science communication efforts of the last two decades on climate change, public polarisation around climate change has intensified (Brin, 2010; Hart & Nisbet, 2012). Quality traditional news coverage only reaches a small audience of already engaged citizens (Swain, 2012), meaning that most publics likely reinterpret such science based on their own sources of information as well as their perceptions and cultural norms. People strenuously defend their own positions on climate change as being evidence-based and the opposing position as being either conspiratorial or ill informed (Brin, 2010). In such high-profile controversial science spaces, there is often widespread confusion and misunderstanding about the science (Schmidt 2008), which is often brought on by the inability of the mediators of science, like journalists and science communicators, to communicate the complexities and uncertainties of the science clearly. This leads to a desire by publics to have more direct access to the scientists (Schmidt, 2008) and to directly question and interrogate such science. The public generally wants to know if the planet is warming, by how much, and in what time frame. They want to know the impacts and the possible ways they can

adapt (Swain, 2012). However, scientists, in accordance with their training in the norms of presenting evidence, often couch their responses in the language of statistical probabilities (Lemonick, 2010), which makes the science harder to understand.

Of further concern, is that some scientists and science communicators have retreated from directly engaging with the public, especially the sceptical or ‘denier’ public. For example, controversial climate scientist Judith Curry, who heads the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology in the United States, says that the: “mainstream climate science community has moved beyond the ivory tower into a type of fortress mentality, in which insiders can do no wrong and outsiders are forbidden entry” (Lemonick, 2010, p. 81). There have certainly been instances of such fortress mentality in the communication of climate science in Australia with leading climate scientists avoiding communication in response to abuse and threats to them and their families (Simon Torok, personal communication).

Another issue with climate change communication is the global nature of the issue, meaning it can lack local relevance, which often leads to climate inaction as people feel disenfranchised and fail to act. It can also lead to national polarisation of views and subsequent government inaction. For example, the USA backing out of the Kyoto Protocol treaty and the failure of successive Australian governments to put a price on carbon. However, where science communication about climate change can appear to make a difference is at the local level, involving smaller groups of people who demand the specific information they need to create change in their local area or sphere of influence (Braun, 2010; Khan et al., 2012). In a paper providing the five ‘best practice’ insights from psychological science for communicating about climate change, van der Linden et al. (2015) say that the global nature of climate change makes people feel powerless, and consequently one of their best practice recommendations is to

“emphasize climate change as a present, local, and personal risk” (p. 758). Despite this, little has been researched about smaller groups of people participating with scientists to solve problems or deal with issues about controversial science like climate change. This was my motivation behind exploring the Climate Champion Program where farmers participate with scientists to explore how climate science can better help them manage their on-farm risks (see Chapter 5).

1.4.2 Failure of science literacy communication on controversial topics

With controversial science issues, such as climate change, there continues to be the belief by many that ‘if only the public understood the science’, they would be able to accept it and understand the need for action or policy change. Bucchi (2004) talks about the failure of science literacy-driven science communication, given that many studies have shown, for example in the biotechnology arena, that increasing communication with the public did not “reduce significantly the likelihood of being hostile to certain biotechnology application, or at least that lack of information cannot be used as the only explanation for public scepticism” (p. 270). Others similarly discuss the failure and futility of facts in winning the fight to communicate climate science to publics (Grant, 2016; Roberts, 2013). Such scholarly research findings indicate that the communication styles and methods theorised for the deficit model may create hostility to science by various publics, rather than helping such publics make evidence-based decisions about new technologies or proposed policies. As such, my comparison of the theorised science communication models with examples of controversial practice in this thesis is intended to provide insight into how theorised science communication can be used or developed for more effective science communication.

1.4.3 Research on science controversies is mostly focussed on linear science communication

Most of the research to date on public engagement in controversial science, including climate change, has focussed on linear (one-way and two-way) science communication such as: media messages and framing; public awareness and gaps in understanding of the science and its impacts; public attitudes to the issues; and strategies to ‘sell’ the technology to the public. For example, a growing body of research investigates the media’s framing of climate science (e.g. Akerlof et al., 2012; Binder, 2010); the framing and language of climate change (e.g. Barr, Gilg & Shaw, 2011; Budescu, Broomwell & Por, 2009); public understanding and literacy about climate change (e.g. Ashworth, Jeannerret, Gardener & Shaw, 2011); and public attitudes to climate change science (e.g. Eckard, 2012). While there has been some analysis of public engagement aimed at changing attitudes to new technologies like nanotechnology or biotechnology (e.g. Delgado et al., 2011; Katz, Solomon, Mee and Lovel, 2009; Lyons & Whelan, 2010; Pidgeon & Rogers-Hayden, 2007), most of this research is directed at whether it was successful or not at changing public attitudes and behaviours or gaining policy support. There has been little exploration of the application of science communication models to practice, and the actors involved in communicating about controversial science.

This thesis explores the role of controversy in shaping science communication models (see Chapter 2). It compares controversial engagement activities with those that are not controversial (see Chapter 3). The thesis also analyses two practical examples of science communication of climate change science. The first example (Chapter 4) compares two Australian-based blogs about climate change—one in support of the science of anthropogenic climate change, and the other against. The second example (Chapter 5) explores the participatory science communication embedded in the Climate

Champion Program where Australian farmers interacted with scientists over a seven-year period (2010-2016).

1.5 Summary of terms used in the thesis

For the purposes of my thesis, when I refer to ‘**science communication**’, I am referring to all forms of public engagement in science from public lectures to stakeholder consultation to deliberative problem solving. This is similar to the broad definition provided by Burns et al. (2003), as described above.

When I use the term ‘**science communicators**’ I am referring to professional science communication practitioners, as well as scientists who do science communication. When I refer to ‘**science communication scholars**’, I am referring to those who study what science communicators do to communicate science to the public, as well as the science communication process.

When I use the term ‘**publics**’ I am referring to all the various sectors of society that are not professionally engaged in scientific research. Publics includes groups which are often referred to as ‘laypersons’, ‘audiences’, and stakeholders.

When I refer to ‘**theorised science communication models**’ I am referring to how scholars have theorised about the postulated science communication models in the literature. This has led to a set of characteristics which are discussed in detail for each model in Chapter 2.

When I refer to ‘**controversial science**’, I am referring to science which is publicly-contested, regardless of whether there is scientific consensus on the issue.

1.6 Australian context

Given that the practice examined in this thesis is based in Australia, it is important to describe the Australian science communication context. This context explains how the

national audit of science engagement activities arose, which is the first practice case to be examined (see Chapter 3). It also provides context for the other two practice cases, which focus on climate change science, which is publicly controversial in Australia.

1.6.1 Australian science communication focused on practicalities

From the very beginning, science communication in Australia has been rooted in the practicalities. The demands of establishing a society in the 1800s in an environment often hostile to European approaches to farming and environmental management shaped the science that needed to be done and hence its discourse. These practical beginnings continued with initiatives during the first and second World Wars, and then afterwards to rebuild the nation (Burns, 2014). Scientists understood that their work to rebuild the nation was ‘unlikely to attract public money unless the general public understood it’ (Burns, 2014, p. 73). This focus on practicalities still bears influence today with the emergence of the “science communicator” professional in the early 1990s. Such a professional was most often employed by the CSIRO mostly to assist scientists to communicate with farmers or government management agencies.

1.6.2 Professionalisation of science communication

In 1994, Australian Science Communicators (ASC) was formed. This was an important milestone in the formalisation of the term ‘science communicator’ and the emergence of a new profession. Until that time people involved in science communication had a wide variety of titles and came from a diversity of educational and disciplinary backgrounds. They tended to operate in a professional vacuum and play a subservient and largely unrecognised role (Metcalf & Gascoigne, 2012). Three years after ASC was established, Australia’s first National Science Week was held, and became the focus for many science communication activities, including those recorded in the 2012 national

audit (see Chapter 3).

Universities in Australia offered courses in science communication prior to ASC's establishment but they were fragmented and often short-lived. The gradual emergence of the new science communicator profession gave energy and purpose to a number of universities. For example, the Centre for the Public Awareness of Science was set up at the Australian National University (ANU) in 1996 to "empower Australians by encouraging in them a confident 'ownership' of modern science, increasing science awareness in the community and improving the communication skills of scientists" (Burns, 2014, p. 75). New units were formed, new courses written, and a training framework established. The need for research followed. Post-graduate qualifications in science communication by coursework and research became well-established at three universities: ANU, University of Queensland, and the University of Western Australia (Metcalf & Gascoigne, 2012). However, due to changes in personnel in the past few years, science communication courses at the University of Queensland and the University of Western Australia have ceased or reduced in their scope.

During the growth of training and research programs there appeared to be a marked shift in the ideological approach to science communication. During the 1990s, science communicators focused on one-way communication via formal education, the media, publications, lectures and static museum displays. This focus probably reflected the professional backgrounds of most science communicators as editors, journalists, teachers and librarians. However, with the professionalisation of science communication through university courses and the growth of science communication careers there appeared to be a shift in science communication practice towards attempts to more actively 'engage' the public (Metcalf & Gascoigne, 2012;

Stocklmayer, 2013). However, whether this shift was real or rhetorical has not been fully examined. My analysis of the 2012 national audit of science engagement activities (see Chapter 3) provides some insight into this question.

Today, it is common-place for Australian research and government organisations to advertise ‘science communicator’ positions and there is now a rich diversity of science communicators in Australia, ranging from those working for research organisations like CSIRO to those working in thriving private consultancy businesses. More than 500 communicators attended ASC’s national conference in February 2014, which also celebrated ASC’s 20th anniversary.

1.6.3 Government support for science communication

Australia’s first national government program to support science communication, the Science and Technology Awareness Program (STAP), followed the release of a report prepared by The Royal Society in the UK in 1985. This report, which became known as the ‘Bodmer Report’ after the name of its Chair (Dr W.F. Bodmer), influenced science communication globally. It recommended actions for scientists, educators, the media, industry, government and museums, aiming to increase overall awareness of science and the way it pervades modern life:

Science and technology play a major role in most aspects of our daily lives both at home and at work. Our industry and thus our national prosperity depend on them. Almost all public policy issues have scientific or technological implications. Everybody, therefore, needs some understanding of science, its accomplishments and its limitations. (The Royal Society, 1985, p. 6)

The influence the Bodmer Report had on Australian science communication policy are typical of those that UK institutions have had globally on science communication:

“Initiatives in this area, particularly institutional programmes in the public

understanding of science, have frequently become exemplars for other countries when developing their own” (Lock, 2011, p.18).

STAP was Australia’s first national science communication program. Created in 1989, it had seven staff and a budget in 1991-2 of \$AU0.7 million, rising to \$AU1.7 million in 1992-93 (10 cents per head of the population of Australia). These were modest resources given its ambitious aims:

The Government's Science and Technology Awareness Program aims to increase public awareness of the central role that science and technology play in national life, including economic and social development. The contribution of science and technology to industry, and the contribution of our manufacturing and services industries to national development, are not widely recognised by Australians. This lack of recognition appears to be one reason for the reluctance of Australians to adopt new technologies and innovative practices in the workplace. (Australian Government, 1992, p. 4)

STAP’s five target groups were young people and their teachers; women; industry and business leaders; scientists; and journalists. Over a decade and a half, successive governments tinkered with the program, not satisfied it was making much of a difference. The Australian community was not engaged, student numbers in science were falling, and investment in research by industry was among the lowest in the Organisation for Economic Co-operation and Development (OECD), which was of concern to some Australian policy makers (Australian Government, 1992).

In response to the perceived need to better engage the public, the Australian Government’s Department of Industry, Innovation, Science Research and Tertiary Education commissioned the *Inspiring Australia* strategy (Australian Government, February 2010), which aimed to deliver a “coordinated national approach to science communication... for a more scientifically engaged Australia” p. xvii). The strategy defines “a scientifically engaged Australia” as “a society that is inspired by and values

scientific endeavour, that attracts increasing national and international interest in its science, that critically engages with key scientific issues and that encourages young people to pursue scientific studies and careers” (p. 2-3). These four descriptors of an engaged society are also the basis for the four desired outcomes of the *Inspiring Australia* strategy.

The strategy (Australian Government, 2010) included 15 recommendations, the last of which recommended research such as “baseline and longitudinal, attitudinal and behavioural studies, activity audits, program evaluations and impact assessments” (p. xx). The purpose of this research was to develop the “strategic research and evaluation capability to design, target and review effective science engagement activities and to guide future investment” (p. xx). The 2012 audit of science engagement activities studied in Chapter 3 of this thesis delivered one of these research outcomes.

1.7 The research questions

The problem I address in this thesis is: how well does the practice of science communication, especially when the science is publicly controversial, reflect the theorised models of science communication? I have four subsidiary research questions that allow me to explore this problem, within an Australian context, but in ways that are relevant internationally.

- (1) How well do theorised science communication models predict practice?
- (2) What science communication models are prevalent in science communication practice?
- (3) Using the example of climate change science, how useful are deficit, dialogue and participatory means of science communication in engaging the public in a controversial issue?

- (4) What implications and conclusions can I draw from my analysis of the nexus between science communication theories and practice?

This study explores the fit between theorised science communication models and what happens in the practice of science communication, and what that means for the further theoretical development and practice of science communication.

1.8 Overview of data and methods

The type of data and analytic methods used to investigate each of the practice case studies varies according to each particular case study and is explained fully in each chapter.

The first data set analysed in this thesis is the raw data collected through a 2012 national audit of science engagement activities in Australia. The audit used an online survey to collect data from 415 science engagement activities happening between 2010 and 2013. My analysis of the audit data went beyond that which was reported to the commissioning agent, the Australian Government's *Inspiring Australia* program in the 'National report of Australian science engagement activities' (Metcalf, Alford & Shore, 2012). The data studied for my second case study on climate change blogs were three sets of comments to the two antithetical blogs—www.skepticalscience.com and www.joannenova.com. I chose three extreme climate change events when both these blogs were likely to attract interest and comment at around the same time on the same specific topics. The sources of data for my analysis of the Climate Champion Program were qualitative and quantitative responses to online surveys and transcripts of six discussions between farmers and scientists which happened at a facilitated workshop in 2014.

Each data set was compared with the theoretical framework of selected characteristics of the theorised deficit, dialogue and participatory models of science communication that arose from my literature review (Chapter 2). For qualitative data, I used thematic content analysis. I first used a deductive approach to analyse responses against the literature-based framework. I then used an inductive approach to identify any further characteristics not present in the literature. The data generated by discussions (climate blogs in Chapter 4 and workshops in Chapter 5) were analysed by using Kouper's (2010) four modes of participation. Inter-coder reliability was checked through an independent researcher who coded a sample of qualitative data sets. The quantitative data (from surveys in Chapter 3 and 5) were analysed using descriptive statistics.

1.9 Overview of chapters

In Chapter 2, I review the literature to set up the framework for comparing the theorised science communication models with three practice examples. The first practice example I compare to the models is the 2012 audit of Australian science engagement activities (Chapter 3). In this example, I also compare controversial and non-controversial engagement activities to see if there are any differences in model fit. The second practice example I use is two prominent blogs on climate change (Chapter 4). Social media, compared to traditional media, is thought by many to be an important dialogic tool, therefore I will look at the dialogic model of science communication in detail. The third practice example is a long-term Australian participatory program bringing together farmers with scientists (Chapter 5). The choice of these three practice arenas was deliberate. As I discuss in each of those chapters, there has been no research comparing the theorised models with a national record of science engagement activities; there has been very little research into how blogs on a controversial topic work as a

dialogic tool between the commenters engaged with them; and most research into participatory science communication programs has focussed on one-off short-term events rather than a longer-term agenda of participation. My last chapter draws all the analyses together to look at the implications for theory and practice, and to suggest a new nexus model of science communication. In the final chapter I also outline the implications for strategic science communication practice from my research and consideration of the models.

As the focus of each example chapter is different, some of the literature review findings are repeated and extended in these chapters. Each chapter includes its own methodology, which is mostly a mix of qualitative research methods, and some quantitative methods (especially in Chapter 3).

At the time of writing this thesis, a large part of Chapter 3 has been published online in the *Public Understanding of Science* journal under the title, ‘Comparing science communication theory with practice: An assessment and critique using Australian data’ (January 2019)¹. I have also had numerous conference papers accepted, based on chapters 2, 3, 4, 5 and 6. I am co-author of a chapter in a book comparing science communication and education, based on parts of chapters 2 and 6: *Motivating Engagement*².

¹ Metcalfe, J. (2019). Comparing science communication theory with practice: An assessment and critique using Australian data. *Public Understanding of Science*.
<https://doi.org/10.1177/0963662518821022>

² Masson AL., Metcalfe J., Osseweijer P. (2016) *Motivating Engagement*. In: van der Sanden M.C.A., de Vries M.J. (eds) *Science and Technology Education and Communication*. International Technology Education Studies, vol 15. SensePublishers, Rotterdam

2. Literature review—Public science controversies drive theorised science communication models

2.1 Introduction

The first part of this chapter provides an overview of modern science communication over the past 30 years in western English-speaking countries, especially the United Kingdom, the United States and Australia. This overview shows how public science controversies have driven policies and actions, with policy makers and professional science communicators seeking new ways to communicate or engage with people about science, especially as it becomes more controversial. Concurrently, science communication scholars have developed and theorised about models of science communication that have emerged along with, or perhaps as a result of, these changes in policy and practice. In the second part of this chapter, I will investigate and compare the science communication models, and the theories about them, that have emerged in the literature. Lastly, I will look at some of the critiques of the science communication models that have arisen and point to the research of this thesis, as described in the subsequent three chapters.

2.1.1 Setting the modern science communication scene

This thesis is set in the contemporary science communication scene of the last 30 years. The motivations and drivers for scientists to communicate with the public have evolved over this time, and this has often reflected political imperatives as well the need for social, political and economic change. The politics associated with change has meant the rise of publicly contested science; for example, the science associated with genetic modification of food, biotechnology, nanotechnology, climate change and more recently, synthetic biology.

As the nature, politics and drivers of public science communication have evolved, so too have the actors. Many countries now have professional science communicators to support scientists and their institutions to communicate (Cormick et al., 2015; Gascoigne et al., 2010; Mullahy, 2004; Treise & Weigold, 2002). Along with the rise of the science communication profession, are associated university education courses, and professional associations, as well as national and international conferences. For example, the PCST Network has organised 15 biennial conferences since 1989. Concurrent with these changes has been an increase in scholarly research about science communication, including the emergence of three academic journals devoted to the topic of science communication: *Science Communication*, *Public Understanding of Science* and *Journal of Science Communication*.

2.2 Public controversies drive new policies and ways of doing science communication

In the early 1980s science communication efforts in many English-speaking countries still largely focussed on science popularisation (Knight, 2006). This included a focus on the need for science literacy, where the public were ‘imagined’ as empty vessels needing to be educated with scientific knowledge (Irwin, 2006). Science literacy efforts are considered to use the one-way *transfer* of knowledge from scientists to the public and are associated with concepts such as “‘reception’, ‘flow’, ‘distortions’ and ‘target’ when discussing communication” (Bucchi, 2004, p. 270). The issue with such one-way transfer of knowledge, argue scholars, is that it assumes that knowledge can be transferred intact from scientists to publics, and that once publics have this knowledge, they would react to the information with the same attitudes and behaviours as the scientists. Irwin (2008) captures the essence of this one-way transfer in the following description: “Science is presented as the embodiment of truth and the task of

governments (or scientists) becomes one of bringing rationality to human affairs” (p. 203). Einsiedel and Thorne (1999) argue that emphasising science literacy suggests that scientists hold the belief that people need basic scientific knowledge in order to function well, and that such knowledge is both certain and fixed. In many ways, science communication with a science literacy objective was perceived to be much more like public education *about* science than about public engagement *with* science. However, in contrast, Hackling, Goodrum and Rennie (2001) provide a much broader interpretation of ‘scientific literacy’ when they describe it as:

...a high priority for all citizens, helping them to be interested in and understand the world around them, to engage in the discourses of and about science, to be skeptical and questioning of claims made by others about scientific matters, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being. (p. 7)

While talking about scientific literacy in the context of Australian school science, the outcomes presumed from scientific literacy by these authors goes beyond what science communication scholars usually argue science literacy can achieve in itself. This is especially true given that the dominant one-way methods used to communicate for science literacy outcomes still include lectures, presentations, displays and publications.

During the mid to late 1980s, there were increasing signs of public unease with the one-way communication from scientists to the public that appeared to dominate most science popularisation and science literacy efforts. It was during this time that scientific controversies about HIV AIDS, new reproductive technologies, pollution, environmental change and food safety arose (Benneworth, 2009; Irwin & Wynne, 1996; Jackson et al., 2005). In the USA, Jasanoff (2003) described how a “spate of highly-publicized cases of alleged fraud in science [in the 1980s] challenged the reliability of

peer review and, with it, the underlying assumptions concerning the autonomy of science” (p. 229). These cases led directly to increased Federal powers for supervising science, including the need for scientists to justify the public money spent on it. The National Science Foundation’s peer review criteria changed in the 1990s to require reviewers to assess proposals on both technical merit and social implications.

Similarly, the 1990s was a seminal decade for the UK’s science communication, especially relating to mad-cow disease, or Bovine Spongiform Encephalopathy (BSE), which was badly communicated by both scientists and government officials. The BSE crisis built up over the decade and remained a lively topic of public debate for some time afterwards (Irwin, 2014). Genetically modified organisms and their potential effects on food safety and the environment became an even bigger and more widespread public controversy in the UK towards the end of the 20th Century. During that time people began to question the relationships between science and policy, and science and publics (Irwin, 2001). As a result, policy makers at some government and scientific institutions began to emphasise the need for greater openness and consultation with the public. Late in the 1990s, those involved in science communication (policy makers, researchers and communicators), and the policies around science communication, began talking about engaging the public more directly in science. This was evident in the UK House of Lords Select Committee on Science and Technology’s report in 2000, which recommended direct dialogue with the public as being integral rather than optional to science-based policy making. This drive towards more interactive science communication, which involved scientists consulting, debating and talking with the public, was due to four factors, according to Benneworth (2009):

1. a more suspicious public following controversial issues such as BSE and Genetically Modified (GM) food;

2. changes in how knowledge is produced with increased scientific collaboration and networking about innovation;
3. greater competition to get ideas across through the Internet and multiple sources of information; and
4. the increasing influences of pressure groups and populist movements, which challenged representative democracy systems.

With controversial science issues, there continues to be the belief by many that ‘if only the public understood the science’, they would be able to accept it and understand the need for action or policy change. Bucchi (2004, p. 270) discusses the failure of communication that is science literacy-driven. He says many studies have shown, for example in the biotechnology arena, that increasing communication with the public does not “reduce significantly the likelihood of being hostile to certain biotechnology application, or at least that lack of information cannot be used as the only explanation for public scepticism”. However, for many science communicators, there still seems to be the dominant assumption that science literacy is both the problem and the solution to societal debates and conflicts (Nisbet & Scheufele, 2009).

Some scholars argue that dialogue-style communication was developed as a means of helping scientists and their institutions regain trust. Dialogue-style communication methods were considered to be particularly relevant when policy makers and scientists perceived that controversies arose because the public had an inadequate understanding of the operation of science (Irwin, 2001). In many ways, dialogue thinking assumes that at some point in the past, the public understood and respected science but then stopped doing so (Nisbet & Scheufele, 2009). In the USA, “this so-called golden era is often described as the dozen or so years of the ‘Space Race’, the period that stretched from the 1957 Russian launch of the Sputnik satellite to

the U.S. lunar landing in 1969” (Nisbet & Scheufele, 2009, p. 1767). After the “golden era”, the public presumably became more critical of science, hence necessitating more deliberative forms of communication.

Dialogue-style science communication appeared to manifest itself in two ways. Firstly, and primarily, instead of ‘telling’ the public about science findings to achieve popularisation and science literacy objectives, scientists were now prepared to engage in dialogues with publics to help explain science through activities like ‘café scientifiques’, open days, science festivals, demonstrations and public events. Secondly, and less commonly, scientists were now prepared to listen to and to consult publics about their perceptions, concerns and needs with regards science. Trench (2008) uses Britain’s Biotechnology and Biological Research Council as an example of an institution adopting the new style of science communication. According to Trench (2008), in the 1990s, the Council stated that they had a new program of activities that would lead to greater transparency and open debate about science, and hence improve public confidence in science.

A number of government reports followed the UK House of Lords report after 2000. These reports repeated and further articulated the call for greater public engagement in science. They also demonstrated a growing critique of dialogue practices. Critics argued that scientists and their institutions were paying lip service to public concerns and local knowledge and there was still a “condescending assumption that any difficulties between science and society are due entirely to ignorance and misunderstanding on the part of the public” (Jackson et al. 2005, p. 350). Science literacy efforts appeared to still dominate science communication, and while some attempts were being made to involve publics in dialogue, they often appeared to be done to legitimise the science that was already being done.

A similar critique of dialogue attempts was happening in the USA. Discussing attempts to engage the public in controversial science, Nisbet & Scheufele (2009, p. 1767) write:

Many of these initiatives start with the false premise that deficits in public knowledge are the central culprit driving societal conflict over science, when in fact, science literacy has only a limited role in shaping public perceptions and decisions.

Likewise, Jasanoff (2003) looked at how public controversies in the USA over innovations such as GM foods and stem cell research had increased the power of ethics committees, negating the need for public discussions: “Frequently, however, these bodies are used as ‘end-of-pipe’ legitimization devices, reassuring the public that normative issues have not been omitted from governmental deliberation” (p. 241). Such critiques resulted in a move by some policy makers and advisers towards science communication that engaged the public ‘upstream’ rather than ‘downstream’, meaning the public were engaged from the start of research rather once it was finished and peer-reviewed. For example, Joly and Kaufmann (2008) reported on the then recent UK Government ten-year strategy for science and innovation which committed to enabling ‘upstream’ public debate to happen before scientific and technological developments had already produced products, which perhaps publics did not even want.

One example of the move towards increased public participation in the USA was the 21st Century Nanotechnology Research and Development Act released in 2003 by Congress to mandate public engagement in nano science and technology. This Act was unprecedented in USA history (PytlikZillig & Tomkins, 2011). Public engagement, Congress indicated (PytlikZillig & Tomkins, 2011, p. 198):

...promises the possibility of interconnections among science, technology and society, allowing science and society to shape one another, and providing a critical element for understanding the ethical, legal, and other societal impacts of new technologies on individuals and societies.

Such policies appear to encourage science communication where publics can participate on a more equal basis with scientists and have some power in directing and shaping science according to societal needs.

Similar policies and strategies have been developed to some extent in Australia. In February 2010, the Australian Government's Department of Industry, Innovation, Science Research and Tertiary Education commissioned the *Inspiring Australia* strategy which aimed at four outcomes to:

create a scientifically engaged Australia—a society that is inspired by and values scientific endeavour, that attracts increasing international interest in its science, that critically engages with key scientific issues and that encourages young people to pursue scientific studies and careers. (p. xvii)²

While this strategy mainly focuses on promoting science for public interest and recruitment purposes, it also specifically talks about critically engaging the public in scientific issues. Other countries, similarly, had strategies and some even looked to the Australian strategy as a model for their own funded strategies, for example Canada (Council of Canadian Academies, 2014).

Such policies and strategies appeared to seek more deliberative forms of engagement. Jasanoff (2003) argued that the participatory engagement of publics involved making “explicit the normative that lurks within the technical; and [acknowledging] from the start [of research] the need for plural viewpoints and collective learning” (p. 239). More participatory forms of science communication appear to be different to popularisation, science literacy and dialogue in that they

recognise and acknowledge various publics as being equal in terms of the power and knowledge they hold when compared with scientists and policy makers. Publics have the ability to reflect upon, share knowledge about, create new knowledge, and make decisions about science that affects society. To what extent more participatory engagement with publics has happened in recent years is debatable. Some argue that science governance needs to be open to this style of science communication, and that in many cases it is not (Stilgoe et al., 2014).

As can be seen, public science controversies have driven changes in policies related to science communication. They have also led to calls for different styles of communication; from one-way communication to two-way, and then to one that is even more open and participatory. However, whether any of these styles have improved science communication, especially on controversial topics, is vigorously debated by scholars, as the next section describes. Paralleling these changes in policy and practice has been a growing literature postulating and theorising about science communication models. These models also appear to be driven by scholars' perceptions of the changes in relations between scientists and publics with more controversial and open science.

2.3 Science communication models

As an academic field of research, science communication draws its theories, models, approaches and methodologies from a range of disciplines: sociology, humanities, psychology, linguistics, philosophy and, more recently, communication and political science (Gascoigne et al., 2010; Trench & Bucchi, 2010). This gives the field a richness and diversity it may not otherwise have but it can also mean theoretical fragmentation. In discussing the models of science communication that are described in the academic literature and how they have been theorised about in the literature, it is important to emphasise that these descriptions represent how scholars argue that science has been, is

being or should be communicated.

Three dominant models of science communication have been developed. The ‘deficit model’ of science communication, where scientists communicate in a one-way direction to publics, was first discussed in the literature during the 1980s and early 1990s (Durant, Evans & Thomas, 1992; Millar & Wynne, 1988). Scholars juxtaposed this model with the ‘dialogue model’, which some scholars separated from a third model, the ‘participation’ model. Other scholars dispute the distinction between the dialogue and participation models, theorising that they are both more deliberative models of communication in that they seek to involve publics on a more democratic basis with the science, whether this be through consultation or joint problem-solving (Horst & Michael, 2011; Kurath and Gisler, 2009; Nisbet & Scheufele, 2009; Rowe & Frewer, 2005). However, I distinguish between these two models by seeing ‘dialogue’ as being the science-directed two-way interaction between scientists or science communicators and the public, and ‘participation’ as being a more obvious shift in power away from scientists to the various participants, which includes scientists, who are having multiple interactions in many directions. A number of scholars (e.g. Bucchi, 2008; Callon, 1999; Rowe & Frewer, 2005) also theorise a multi-model framework to encompass and separate deficit, dialogue and participation. The three models of science communication parallel the different styles of science communication that arose, as discussed in the previous section. A summary of this literature describing science communication models is shown in Table 1.

Table 1. A summary of science communication models as theorised by scholars

Scholar	Model 1: Deficit	Model 2: Dialogue	Model 3: Participation
Callon, 1999	Public education model where scientists teach the public everything to eradicate superstitions and lay beliefs; guard against lay	Public debate model where science involves specific sectors of the public with different competencies and points of view to complement	Co-production of knowledge model where the people are actively involved with scientists to collectively learn and coproduce new

Scholar	Model 1: Deficit	Model 2: Dialogue	Model 3: Participation
	contamination of science; overturn public mistrust	scientific knowledge with lay observations; find out and use public opinion to make decisions about science, especially contested science	knowledge; jointly solve a specific problem
Durant, 1999	Deficit model where scientists are the knowledgeable experts transferring knowledge to the ignorant lay people, to meet the needs of public interest; ensure public support for science; respond to opposition to science	Democratic model that recognises the existence of multiple forms of expertise, and seeks to accommodate them all through open and constructive debate to accommodate multiple forms of expertise; use debates as a basis for democratic decision making; address the growing distrust of science and scientists	
Miller, 2001	Deficit model where scientists communicate in a top-down one-way process to a scientifically illiterate public to increase knowledge and love of science; reduce ignorance, fear and loathing of science	Contextual model where scientists have scientific facts, the public has local knowledge and an interest in the problems to be solved. Scientists uses dialogue to communicate with the public to understand the nature and existing knowledge of the audience	
Trench and Junker (2001) (Note: Trench and Junker talk about a spectrum from monologic to dialogic rather than providing discrete separation between models)	Deficit model Dissemination model Both with one-way communication from scientists to public to educate the public about science being the leading source of knowledge; persuade of the benefits of science and science careers; help public handle scientific topics more rationally	The duty model The dialogue model Both with two-way communication between scientists and the public to learn from their questions and contributions; to be more accessible; consider ethical and social implications; be more accountable to public funding	The deference model, where scientists engage with the public to involve them in the policy process; participate with other cultural interests
Rowe and Frewer (2005)	Public communication – from scientist to the public to convey information	Public consultation – where scientists consult the public to find out currently held opinions on the topic of interest	Public participation- where the public participate in the science to exchange information and transform the opinions of all parties
Lewenstein (2005) Brossard & Lewenstein (2010)	The deficit model to improve public support and funding; improve knowledge and therefore decision-making	The contextual model where scientists consult the public to understand how people respond to information and thus communicate better with them The lay expertise model to understand and value lay knowledge alongside scientific	The public engagement model where the public participate in the science to integrate citizen views and knowledge into policy debates

Scholar	Model 1: Deficit	Model 2: Dialogue	Model 3: Participation
Bucchi (2008)	Transfer of information from scientists to public to transfer knowledge; popularise science	Consultation of the public by scientists to discuss implications of research	Knowledge co-production jointly between scientists and the public to set the aims and shape the agenda of research
Irwin (2008)	First order thinking – one-way communication from scientists to public to provide knowledge; solve any difficulties in the relationship between science and society	Second order thinking – two-way communication about the nature of risk to acknowledge uncertainties; generate greater trust in science; to be more democratically accountable about nature of risk; access public knowledge and resourcefulness	Third order thinking – science-public relations put into a wider context with multiple participants and interactions to critically reflect about the relationships between technical change, institutional priorities, and wider issues of social welfare and justice
Pouliot (2009), based on Callon (1999)	Deficit model to disseminate scientific knowledge; inform the public	Public debate model where scientists debate with the public about issues to enrich discussion of socio-scientific issues; find out other views	Co-production of knowledge between public and scientists to jointly produce knowledge
Höppner (2009)	Instrumental – one-way engagement from science to a passive public to endorse favoured decisions; promote outcomes such as trust, consent or behaviour change	Substantive – engagement through public input to find out their diverse views and knowledge to improve agendas and decision-making about science	Normative – engagement to empower the public in agenda-setting and decision-making as is their democratic right
Kurath and Gisler (2009)	Informing – where scientists inform the public to increase scientific literacy; promote science; promote science education	Involving – where scientists involve the public in discussions of science to be more democratic	Engaging – where the public engages with the scientists to deal with socio-technological issues
Science for All Expert Group, UK (2010)	Transmit – to inspire, inform, change, educate, increase involvement, or influence decisions	Receive – to use the views, skills, experience, and knowledge of others, (such as the public) to inspire, inform, change, educate, or help make decisions	Collaborate – to collaborate, consider, create or decide something together
Horst and Michael (2011)	Diffusion – where science knowledge is diffused via some medium to an audience	Deliberation – where the flow of information from the public via some medium has the capacity to transform science and scientists	Emergence – rather than a flow of knowledge from one party to another there is a process of science communication where identities are negotiated, and all are changed through the process of coming together
Palmer and Schibeci (2012)	Type 1 – Deficit model to provide knowledge so citizens can make more	Type 2 – Professional exchange of knowledge between scientists to	Type 4 Deliberative science communication where scientists and the

Scholar	Model 1: Deficit	Model 2: Dialogue	Model 3: Participation
	informed decisions; familiarise citizens with the potential of science	advance a discipline; gain recognition Type 3 – Consultative exchange of knowledge iteratively from scientists to the public and vice versa to share knowledge	public have equal standing within a process that is democratic and deliberative, and citizens are able to influence, contribute to, and drive knowledge agendas
Stocklmayer, 2013	One-way information – designed to inform; affect attitudes and possibly behaviour; educate	Knowledge sharing – to assist policy development; mediate different perspectives; facilitate and integrate interdisciplinary approaches	Knowledge building – to create new meaning or understanding from different sources of knowledge; enable actions where knowledge is integrated to construct new meanings
Scheufele, 2014 (The third model does not match the participation model and is not intended to by Scheufele. Included here for comparison.)	Knowledge deficit to build higher level of public literacy that will result in increased support for science	Public engagement in science with two-way communication between publics and the scientific community to debate scientific, ethical; legal and social issues associated with new technologies	Science communication as political communication, where most communication between scientists and public is mediated through mass or online media, and the aim is to build a news agenda

2.3.1 Deficit science communication model

Callon (1999) theorises the following features of the deficit model.

- Scientists teach the public everything and learn nothing from them.
- Science and public are separate entities and science institutions need protection.
- Technoscience is the source of progress.
- The public needs to have trust in scientists.
- Only representatives in government can make decisions.

Irwin (2014) describes the deficit model as the first of three orders of thinking, with the “first order of thinking being ‘the culture of modernity’, a culture within which science is presented as the embodiment of truth and the task of government becomes one of bringing rationality to human affairs” (p. 163). The deficit model is one-way communication between scientists and publics, where ‘publics’ are imagined as empty vessels needing to be filled with scientific knowledge (Irwin, 2006; Nisbet & Scheufele, 2009). In practice, Nisbet & Scheufele (2009) argue that deficit-style communication

activities are unlikely to improve science literacy or understanding by the *wider* public and will most likely only reach the minority who are already enthusiastically engaged in science. However, other scholars (e.g. Durant, 1999; Miller, 2001; Broks, 2006) recognise the benefits of the deficit model in scientists responding to public interest in science, and in science communicators creating excitement about science.

As science became more controversial, many scholars began to discuss the public's growing distrust in science and scientific institutions and to theorise about the need for more public engagement through 'dialogue' (Dudo, 2012; Powell & Colin, 2009; Wynne, 2006).

2.3.2 Dialogue model of science communication

Scholars theorised that the new dialogue model could regain public trust by being more open and transparent about scientific uncertainties. The theorised model assumes that the public, who were now deemed to have some knowledge and resources of value to scientific dialogue, would respond rationally to such openness (Irwin, 2008). The dialogue model of science communication: "may have become a practical necessity if public policy is to be made – and justified – in circumstances of social and technical uncertainty" (Irwin, 2008, p. 204). Trench (2008, p. 131) describes the dialogue between scientists and the public as being utilitarian in nature; It helps science communicators find out how to more effectively disseminate science and it can be used to consult publics on specific scientific applications. The dialogue model promotes two-way communication but may have varying purposes. Irwin (2008) postulates "that the movement between 'first' and 'second' order thinking is (or should be) more than a matter of changing communication style... Rather than simply replacing the language of deficit with that of dialogue, each approach (at least potentially) draws upon deeper intellectual and political roots" (p. 203). Irwin's second order of thinking theorises

engagement as the two-way communication between scientists and the public about the nature of risk, especially on controversial topics, where:

- public trust is built by science and decision-making about science issues being open and transparent;
- the uncertainties in science are made more apparent where there is a two-way communication about the nature of risk;
- the public is trusted to respond rationally to openness; and
- some publics are seen to bring some useful knowledge and resources to science and policymaking.

Zorn et al. (2012) differentiates the dialogue model from debate or discussion, by arguing that dialogue does not need to resolve conflict or reach agreed decisions; rather dialogue can happen for its own sake. Likewise, Jackson et al. (2005, p. 350) say dialogue is:

...a context in which society (including scientists) can address the issues that are arising from new developments in science... it locates scientific developments in a wider social context and enables the inclusion of a wider range of expertise with regard to the implications of such developments.

Callon's (1999) model of public debate, on the other hand, focuses on engaging people in controversial science, around local rather than national or global controversial issues in order to achieve specific outcomes. Bickerstaff et al. (2010) takes a more cynical view of dialogue, saying it represents a change from arrogance (deficit model) to persuasion, where scientists are merely trying to market their science and gain the public's trust. Regardless of the different views and theories of scholars, supporters of the dialogue model encouraged science communicators to be more deliberative and democratic in their approaches to science communication.

2.3.3 Participatory model of science communication

In the early 2000s, a new participatory model of science communication gained traction in the scholarly literature. The participatory model appealed to scholars who theorised the democratisation of science as a solution to engaging publics in jointly tackling societal issues of concern (Brossard & Lewenstein, 2010; Bubela et al., 2009; Joly & Kaufmann, 2008; Miller, Fahy & ESConet Team, 2009). For controversial scientific issues, like climate change, public participation was argued to be beneficial for critically reviewing research, solving problems or supporting behaviour and policy changes (Few et al., 2007; Höppner, 2009; Marquart-Pyatt et al., 2011).

The participatory model “emphasises deliberative contexts in which a variety of stakeholders can participate in a dialogue, so a plurality of views can inform research priorities and science policy” (Bubela et al., 2009, p. 515). Many scholars argue that the participatory model has the potential to lead towards a greater democratisation of science than the dialogue model (Joly & Kaufmann, 2008; Miller, Fahy & ESConet Team, 2009).

Scholars (Mohr & Raman, 2012; Stirling, 2008) theorise three different motivations for participatory engagement of the public in and with science: *normative*, because the process of participation is the ‘right thing’ to do; *instrumental* where the specific outcomes of the participation are more important than the process; and *substantive*, where outcomes are negotiated and designed by all parties involved in the participative process. Trench (2008) sees participatory communication as a combination of the normative and the substantive when he says it is as much about the process of engagement as about the outcomes, and that it, “takes place between diverse groups on the basis that all can contribute, and that all have a stake in the outcome of the deliberations and discussions” (p. 131). The normative and substantive participatory

models signal a more obvious shift in power than the instrumental model—from the scientists to publics. Scholars theorise that in participatory science communication activities, scientific knowledge is just one of the sets of knowledge brought to the engagement process, along with knowledge from various concerned citizens, sectional interests, and non-government organisations (Callon, 1999; Palmer & Schibeci, 2012; Pouliot, 2009; Rowe & Frewer, 2005). Palmer and Schibeci's (2012) science communication typology is based on looking at the process of knowledge exchange and how relationships are developed among actors depending on the purpose of the exchange, the kind of knowledge being exchanged and the mechanisms of exchange. Their theorised Type 4 deliberative science communication model demonstrates the desired shift in power from scientists to the public where the participants all have equal standing and all forms of knowledge are respected. (Palmer and Schibeci, 2012).

Irwin's (2008) third order thinking aligns with this participatory model and aims to put science-public relations in the wider context by:

- raising profound questions of scientific and political culture;
- recognising that disagreement and controversy bring energy, excitement and focused attention to debates, and as such, are an important resource;
- building new connections between public, scientific, institutional, political and ethical visions of change;
- providing more meaningful scrutiny of the prevailing modes of scientific governance; and
- critically evaluating current approaches to scientific governance and science communication.

Irwin (2008) states that such public engagement in science will “open up fresh inter-

connections between public, scientific, institutional, political and ethical visions of change in all their heterogeneity, conditionality and disagreement” (p. 210). In fact, Irwin’s third order thinking goes beyond what other scholars theorise about participatory science communication models to call for the active and critical scrutiny of science, scientists and science communication and their place within society and its politics.

The participatory science communication model is thought to be particularly suited to public engagement with controversial issues, especially those that deal with people’s health, food safety and environment. But it is thought to be less suited to basic scientific research, which requires specialised equipment and facilities, like particle physics (Callon, 1999). Public participation in controversial science requires processes that draw in everyone with the relevant knowledge and values (Jasanoff, 2003). To go even further, some scholars have called for the public to have more influence over what science actually gets done or not in the first place (Rogers-Hayden & Pidgeon, 2008; Wilsdon & Willis, 2004). Others have theorised that such participatory models need to move ‘upstream’ beyond just consultation and participation to co-creation of science and technologies (Rogers-Hayden & Pidgeon, 2008).

2.4 Comparing science communication models

Each of the three models of science communication has been theorised by various scholars to account for the following aspects: objectives for science communication, who participates in the communication, the relationships between actors, the place of knowledge, the actors’ acknowledgment of risk, methods used to communicate, and the usual timing for the science communication. Not all scholars theorise about each of these aspects of science communication models, but collectively across all the literature there is a rich theorisation about aspects of the three models, which are summarised in

Table 2. As can be seen, the science communication objectives theorised for each model by various scholars identify a variety of possible motivations for applying that model of science communication in practice.

Table 2. Comparison of selected characteristics of theorised deficit, dialogue and participatory models of science communication (Sources: Brossard & Lewenstein, 2010; Bucchi, 2008; Callon, 1999; Durant, 1999; Irwin, 2008; Kurath & Gisler, 2009; Miller, 2001; Palmer & Schibeci, 2012; Pouliot, 2009; Rowe and Frewer, 2005; Scheufele, 2014; Stocklmayer, 2013; Trench & Junker, 2001)

Characteristic	Deficit	Dialogue	Participatory
Objectives	<ol style="list-style-type: none"> 1. Raise awareness of science 2. Inform about science 3. Correct misconceptions 4. Gain support and funding for science 5. Promote careers in science 6. Popularise science 7. Educate in science 8. Address concerns about science 9. Improve decision-making through increased knowledge 10. Respond to interest in science 11. Change behaviours and attitudes 	<ol style="list-style-type: none"> 1. Address mistrust in science 2. Discover public opinion about science and thus communicate more effectively 3. Gain and use lay knowledge 4. Debate / discuss scientific issues 5. Connect with those from other disciplines 6. Be more accessible and accountable to public 7. Engage public in decision-making 	<ol style="list-style-type: none"> 1. Collectively learn 2. Jointly produce new knowledge 3. Jointly solve a problem 4. Participate with public in policy making 5. Participate with cultural interests other than science 6. Shape the research agenda 7. Critically reflect on science
Actors	Scientists, science communicators, public	Scientists, science and government institutions, science communicators, public	Depends on scientific issue to be explored but usually multiple actors
Nature of interaction	One-way, top down	Two way	In multiple directions between multiple actors
Relationship between actors	Scientists have control	Scientific and government organisations have control, but wish to consult or converse	Equal and shared
Knowledge	Scientists have all the necessary knowledge	Scientists have the most important knowledge, but they can gain new knowledge from others	There are multiple sources of knowledge and expertise of equal worth and validity
Acknowledgment of risk	Science portrayed as certain	Risks acknowledged as levels of uncertainty in scientific knowledge	Risk related to the social contexts and values
Example methods of communication	Lectures, presentations, publications, mass media, displays	Café Scientifiques, consensus conferences, citizen juries, surveys, opinion polls, focus groups	Workshops, formal and informal meetings, on-site visits and activities

Characteristic	Deficit	Dialogue	Participatory
Timing of engagement	Usually at the end of science production after peer review	During science production, and after peer review to discuss policy implications	Co-production amongst all actors, starting from the beginning with 'upstream engagement'

2.4.1 Objectives

Scholars describe a mix of objectives for each science communication model. In summary, scholars variously theorise the objectives of science communicators involved in deficit-style communication as being to:

- (1) raise awareness about the potential of science (Palmer and Schibeci, 2012);
- (2) inform people about science and increase their science literacy (most scholars);
- (3) eradicate superstitions and misconceptions, and increase rationality (Callon, 1999; Miller, 2001; Trench and Junker, 2001);
- (4) ensure public support and funding for science, and persuade as to its benefits (Brossard and Lewenstein, 2010; Durant, 1999; Höppner, 2009; Kurath and Gisler, 2009; Scheufele, 2014; Trench and Junker, 2001);
- (5) promote careers in science (Trench and Junker, 2001);
- (6) increase the love of science and popularise it (Bucchi, 2008; Miller, 2001; Science for all Expert Group, 2010; Scheufele, 2014);
- (7) educate about science (Callon, 1999; Science for All Expert Group, 2010; Stocklmayer, 2013; Trench and Junker 2001);
- (8) address public concerns and increase trust in science and scientists (Callon, 1999; Höppner, 2009; Irwin, 2008; Miller, 2001);
- (9) improve decision-making through increased understanding (Brossard and Lewenstein, 2010; Höppner, 2009; Palmer and Schibeci, 2012; Science for all Expert Group, 2010; Stocklmayer, 2013);
- (10) meet public interest and needs (Broks 2006; Durant, 1999); and

- (11) change behaviour or attitudes (Höppner, 2009; Stocklmayer, 2013).

The first eight of these theorised objectives mostly benefit science and scientists rather than publics, although it could be argued that opportunities for a career in science and a love of science can also benefit publics. The last three theorised objectives assume some degree of public benefit from deficit-style communication.

Scholars perceive that science communicators are motivated to use dialogue communication to gain or regain public trust especially in the face of public controversies (Irwin & Wynne, 1996); to find out how to communicate science more effectively with a better understanding of the public (Trench, 2008); and to access useful non-scientific knowledge (Jackson et al., 2005). The objectives theorised for dialogue-style communication are to:

- (1) address growing mistrust of science (Durant, 1999; Irwin, 2008);
- (2) discover public opinion about contested science and use it to better communicate the science or make policies (Brossard and Lewenstein, 2010; Bucchi, 2008; Callon, 1999; Durant, 1999; Höppner, 2009; Miller, 2001; Pouliot, 2009; Rowe and Frewer, 2005; Scheufele, 2014; Stocklmayer, 2013; Trench & Junker, 2001);
- (3) gain and use lay knowledge to complement scientific knowledge (Callon, 1999; Durant, 1999; Irwin, 2008; Pouliot, 2009; Science for All Expert Group, 2010; Trench & Junker, 2001);
- (4) debate or discuss scientific / technological issues and acknowledge uncertainties of science (Bucchi 2008; Durant, 1999; Irwin, 2008; Kurath & Gisler, 2009; Pouliot 2009; Scheufele, 2014);
- (5) facilitate interdisciplinary approaches by making connections between people (Stocklmayer, 2013);

- (6) be more accessible and accountable to the public (Trench & Junker, 2001; Bucchi, 2008; Irwin, 2008; Palmer & Schibeci, 2012); and
- (7) engage citizens more democratically in science and technology issues, including making decisions and formulating policy (Kurath & Gisler, 2009; Palmer & Schibeci, 2012; Scheufele, 2014; Stocklmayer, 2013).

The first three theorised objectives above still largely benefit science and scientists, although allowing public opinion to influence communication processes and policy-making is also likely to benefit the public. The last four objectives provide at least some direct public benefits.

The theorised objectives of the participatory science communication model, which all assume at least some public benefit, are to:

- (1) collectively learn, including accommodating multiple, and sometimes conflicting forms of knowledge (Callon, 1999; Durant, 1999; Rowe & Frewer, 2005; Stocklmayer, 2013);
- (2) jointly produce new knowledge (Bucchi, 2008; Callon 1999; Pouliot, 2009; Science for All Expert Group, 2010; Stocklmayer, 2013);
- (3) jointly solve a specific problem (Callon 1999; Kurath & Gisler, 2009);
- (4) participate with various publics in policy making, and integrate their views (Brossard & Lewenstein, 2010; Höppner, 2009; Palmer & Schibeci, 2012; Trench & Junker, 2001);
- (5) participate culturally with interests other than science (Trench & Junker, 2001);
- (6) shape the scientific research agenda (Bucchi, 2008; Palmer & Schibeci, 2012); and
- (7) critically reflect on science and its institutions (Irwin, 2008).

2.4.2 The actors, their interactions, and relationships

The actors involved in science communication include scientists, various publics, science communicators, journalists, and government policy makers. However, the theorised models focus most on scientists, publics and to a lesser extent government policy makers. There is little recognition of the role of the professional science communicators or journalists.

When science communicators are included in the scholarly literature they are often described as mediators or interpreters of the science. Bucchi (1998) acknowledges that under this description “the problem of communicating science to the public, then, is reduced to a mere matter of linguistic competence” (p. 3). Certainly, science communicators today play a diversity of other roles. In communication activities based on deficit model thinking, they are likely to play the role of a translator or promoter of complex science to the public. With dialogue model activities, science communicators play the roles of mediator, consultant and organiser of activities. In participatory science communication, they play a multitude of roles as part of the ‘concerned group’ involved in the engagement.

Journalists are also players in public engagement, which is not surprising given that most publics experience science through traditional or online media. Journalists are often blamed for any miscommunication or misinterpretation of the science in their articles or productions, which are tools of deficit-style communication. In dialogue engagement, scholars theorise that, “The media not only influence public perceptions, but also shape and reflect policy debate” (Bubela et al., 2009, p. 515). Scheufele’s (2014) third model of science engagement (see Table 1) theorises the medialisation of science where scientists and journalists become increasingly linked, and in so doing jointly affect public perceptions and understanding of science.

In the theorised deficit model, the image of the scientist is one of expertise, trustworthiness and autonomy, which is completely separate to the public (Callon, 1999). In the deficit model, scientists are seen to perceive publics largely as undifferentiated masses, ignorant of science, but perhaps also interested.

In the theorised dialogue models, scientists acknowledge others' expertise as being useful as dialogue emphasises the importance of shared meaning among participants, rather than persuading others to accept a certain way of understanding (Zorn et al., 2012). With the theorised dialogue model, the undifferentiated public of the deficit model is replaced by differentiated sectors with the capacity to access the cultural and ethical implications of scientific endeavour (Callon, 1999). These publics may be well-organised around a specific issue (campaigning publics), may come together as community or Internet based groups (civil society publics) or may be mobilised by other groups or leaders as latent publics (Mohr et al., 2013). With the dialogue model, the public are now theorised to be in a position to negotiate about science and the usual boundaries between scientists and the public are not so distinct (Callon, 1999). However, scientists are still drawn into public debates and discussions as experts compared to "civil society groups or non-government organisations (NGOs) concerned with matters that have significant scientific content" (Trench 2008, p. 127). Scientists' roles in controversies are therefore often limited to producing operative knowledge, formulating evaluative knowledge and interpreting knowledge (Beck & Kropp, 2011).

With the theorised participatory science communication model, publics are neither undifferentiated nor differentiated. Scientific expertise is just one set of knowledge brought to the engagement arena, along with various other concerned publics, including industry and NGOs. With the theorised participatory science

communication model, scientists and their institutions may not necessarily initiate or manage the participatory process. Public participation in science, therefore, often results in contested relationships between science, government and NGOs (Hadgendijk & Irwin, 2006). Scholars theorise that participatory communication brings about greater reflexivity by various publics (Bucchi, 2008; Höppner, 2009; Irwin 2008; Kurath & Gisler, 2009). This reflexivity is theorised to emerge alongside a ‘concerned group’ where relationships between various participants are contested and negotiated over a period of time (Callon, 1999; Elam & Bertilsson, 2003; Hadgendijk & Irwin, 2006).

2.4.3 Knowledge

Knowledge (its definition, use and place) is an important differentiator of the three different theorised science communication models. The relationships between the actors involved in public engagement of science and technology is theorised to affect how knowledge is disseminated and shared, and this tells us about the nature of the engagement. In the theorised deficit model, the only knowledge that is valued is that of the expert. The knowledge of publics is not used or credited (Irwin, 2008). The theorised image of science in the deficit model is one of unity with clearly-defined methods and knowledge. With the theorised dialogue model, the public’s knowledge is recognised and valued, but it is not given the same status as scientific knowledge (Hadgendijk & Irwin, 2006) or integrated with scientific knowledge for policy making purposes (Irwin, 2008). Some scholars theorising about the science communication activities typical of the dialogue model postulate that they are often limited to discussions of ethics and values rather than questioning the science or the scientific institutions (Hadgendijk & Irwin, 2006). However, Goulden (2013) argues that information gathered in public forums can influence science knowledge creation.

The theorised participatory science communication model recognises, values and discusses knowledge from a variety of sources; “knowledge derived from scientific research is just one ingredient of policymaking and public debate, and scientists are called upon to open ‘science-in-the-making’ for public scrutiny” (Trench, 2008, p. 126). The participatory model is theorised to delimit a clear change in the way knowledge is produced. ‘Concerned groups’ will co-produce knowledge that takes into account the complexities of local situations. Knowledge from the general to the specific is appropriated, discussed and adapted by a hybrid collective composed of concerned lay people and specialists (Callon, 1999).

2.4.4 Acknowledgment of risk

The way in which scientific risk is explored during engagement differs across the theorised science communication models. Deficit model communication is theorised to have a language of certainty. Scientists talk about risks objectively as probabilities that the public should accept on face value (Callon, 1999). Irwin (2008) asserts that “This ‘science centred’ approach to risk management and risk communication takes little account of the diversity, nor the possible *knowledgeability*, of publics” (p. 201). The theorised dialogue model acknowledges uncertainties and aims to bring the public in early to discuss and explain any risks. With the theorised participatory model, the ‘concerned group’ ideally examines all uncertainties and risks. Risks are transparent and known and the ‘concerned group’ will discuss options for dealing with risks within the context of the local situation.

2.4.5 Methods for communicating

The approaches theorised for the three science communication models both reflect and lead to different methods for science communicators to use when communicating to

publics. The linear approaches theorised for both the deficit and dialogue models means traditional forms of science communication are more likely to be employed, which are often one-off events. For the deficit model this includes events such as lectures, publications, mass media stories, and static displays (Stocklmayer, 2013). For the theorised dialogue model where two-way deliberative interactions between scientists and publics are considered desirable, typical theorised science communication approaches include events, usually managed and directed by scientists and their institutions or government agencies, like Café Scientifiques, consensus conferences and citizen juries, citizens' panels, and also the use of social media for issue engagement (Davies et al., 2009; Einsiedel et al., 2001; Hetland, 2017; Pidgeon & Rogers-Hayden, 2007; Prikken et al., 2011; Zorn et al., 2012). When representatives of government agencies and scientific organisations consult publics to find out their knowledge and opinions of science, as also postulated by the theorised dialogue model, they typically use surveys, opinion polls and focus groups.

In contrast, the theorised participatory model of science communication involves publics working on an equal basis with scientists over a significant period of time to solve problems through a 'concerned group' (Callon, 1999; Elam & Bertilsson, 2003; Hadgendijk & Irwin, 2006). As such, their interactions are most likely to be face-to-face, and continuous as relationships are developed and negotiated. Participatory science communication is more likely to include workshops, joint visits to sites of interest, and regular opportunities for formal and informal meetings.

2.4.6 Timing of science communication

The time that science communication occurs in the scientific process differs across the three models. In the deficit model, communication is theorised to be generally carried out after peer reviewed research has been completed and published. Dialogues about

scientific issues are theorised to be mostly driven by government or scientific institution agendas, which can be too late with the timing of public debates impeding consultative engagement (Irwin, 2008). However, if the public are not involved early in the scrutiny of science, some scholars postulate that there are risks that the public will react more strongly later when the research outcomes or applications are presented, and they are contrary to publics' values or expectations (Jackson et al., 2005, p. 353). The participatory model is theorised to include 'upstream' engagement where scientists engage with concerned publics before the research has started, sometimes at the instigation of concerned publics (European Commission, 2007; Goulden, 2013; Jackson, 2006). Jasanoff (2003) says:

Sustained interactions between decision-makers, experts and citizens, starting at the upstream end of research and development, could yield significant dividends in exposing the distributive implications of innovation. (p. 242)

Therefore, in the theorised deficit model science communication happens at the end of research to disseminate findings; dialogue model science communication happens during research and after research has been published to discuss policy implications; and participatory science communication occurs throughout but is theorised to commence before research starts. According to the theorised participatory science communication model, scientific research may even be initiated and driven by the concerned group who have formed around a common problem.

2.5 Scholarly critique of successive models

The more controversial science becomes with the public, the more that various actors call for different styles of engagement as traditional means of science communication are perceived to fail in practice (Irwin, 2008, 2014). In response, scholars theorising about science communication progressively moved to an idealised

participatory model where the actors were viewed as equal in terms of their power, the value of their knowledge, and their capacity to drive societal change for good. This scholarly shift paralleled a society increasingly prepared to contest science and its effects on their society, culture, economy and environment.

However, the theorised transition from one model to the next often appears to be predicated on blame, with most of this blame being placed on scientists and their institutions. For many scholars, the deficit model of science communication appeared to emerge when scientists and their institutions became concerned about poor science literacy and the impact of this individual and political decision making. However, with the enactment of deficit-style science communication and the rise of public controversies, scholars began to blame scientists and their institutions for not recognising the needs or concerns or knowledge of the publics they were informing through deficit-style communication. Deficit style communication was perceived by many scholars to fail in practice. For example, Hart and Nisbet (2012) discuss the failure of deficit style communication with climate change:

The deficit-model of science communication assumes increased communication about science issues will move public opinion toward the scientific consensus. However, in the case of climate change, public polarization about the issue has increased in recent years, not diminished (p. 701).

Simis et al. (2016) studied why the deficit model persists in science communication, and they found four causes: the academic training of scientists which means they perceive publics will react rationally to information they receive; the lack of training of scientists in communication skills; the perception by scientists of the public having a deficit of important knowledge; and the perception by scientists and their institutions that evidence-based knowledge can influence public policies. Again, the overriding rhetoric is one of blame for scientists and their institutions maintaining deficit-style

communication.

The dialogue model arose in response to this style of blame, but then scholars again criticised scientists and their institutions in the literature, by bemoaning the continual reinvention of the deficit model in dialogue style practice (e.g. Bickerstaff et al., 2010; Cortassa, 2016; Irwin, 2008; Ishihara-Shineha, 2017; Wilsdon & Willis, 2004; Wynne, 2005). These scholars discuss the perceived practical failure of the dialogue model to be applied in such a way as to deliver societal deliberation on science controversies. Instead, application of the dialogue model was seen by these scholars to be mostly about gaining a social licence to continue doing what they always wanted to do with their research and development agendas. Moreover, when the science is controversial some scholars argue the continued application of the deficit model strengthens the controversy; “continued adherence to the deficit model only likely fans the flames of science conflicts. Condescending claims of ‘public ignorance’ too often serve to further alienate key audiences” (Nisbet & Scheufele, 2009, p. 1768). Wynne (2006, p. 214) argues that the deficit model continues to be reinvented in order to overcome mistrust of science where there is a public deficit of:

- understanding of scientific knowledge;
- trust in science, where “more information, transparency or explanation will restore trust”;
- understanding of the scientific process – “science cannot *be expected to* give certainty or zero risk”;
- understanding “that ‘real’ science has no ethical/social responsibility for its applications or impacts”; and
- knowledge of the benefits of science.

Sturgis (2014) says a new orthodoxy has arisen with the scholarly discussions about the failure of the deficit model:

In place of the much-lamented ‘knowledge-deficit model’ of the public’s relationship with science and technology have come approaches which, in different ways and to varying degrees, emphasise the importance of ‘two-way dialogue’ between science actors and the public. (p. 38)

This scholarly discussion of the deficit model continuing to exist or being reinvented is pejorative in nature—application by scientists and science communicators of deficit style communication is largely perceived as negative. Scientists and science communicators are blamed for continuing to use deficit style communication or to reinvent it through the guise of dialogue-style communication.

The participatory model of science communication is theorised by many scholars as being the most desirable model for practitioners to aspire to, especially when the science is controversial and when deliberation by publics is seen to be important for policy and decision making. However, some research has also been critical of how this has been carried out in practice. For example, Braun and Schultz (2009) looked at participatory programs associated with genetic testing in Germany and the UK and found that the participatory arrangements initiated by scientists and their institutions were more about knowledge generation and education than about deliberation or decision making. In other words, these participatory programs also used deficit style communication, for which the scientists and their institutions could be blamed.

This focus by scholars on blame when theorising about the science communication models could further alienate scientists and science communicators from science communication scholars and may mean they are even less likely to pay attention to scholarly research. It could also mean that the theorising that most scholars have done about the three models may not reflect the reality or the desired reality of

science communication practice. This thesis tests the reality of science communication practice against how the three models have been theorised in the literature.

An important question to consider is when it is desirable or even feasible to completely discard the deficit model of science communication. And is application of the theorised dialogue and participatory models of science communication practical, or always necessary? Some scholars say not, and some point to the genuine interest of at least some publics in accessing the knowledge of scientists often through a one-way process of lectures and publications (Broks, 2006; Durant 1999; Miller, 2001). The late David Dickson who initiated the SciDev.Net, an online portal for science stories of relevance to developing countries, made the case (2005) for retaining the deficit model of science communication, especially for providing accurate knowledge to inform policy and for journalists writing about science in developing countries:

The process of democratic dialogue over science and technology-based issues is critical to the effective functioning of modern societies. But providing reliable information in an accessible way — in other words, filling the relevant 'knowledge deficit' — is an essential prerequisite of both healthy dialogue and effective decision-making. (<https://www.scidev.net/global/communication/editorials/the-case-for-a-deficit-model-of-science-communic.html#>)

Dickson's article was one of the first to point to the possible and necessary coexistence of the science communication models in practice. Some science communication scholars have also noted this possibility without exploring in detail how this affects the theorising of science communication models (e.g. Brossard & Lewenstein, 2010; Bucchi, 2008; Hetland, 2017; Irwin, 2014; Jensen & Holliman, 2015; Trench, 2008). Trench (2008) argues that models can coexist when the choices are made explicit. Irwin (2014, p. 160) says that there is no sequence between his postulated three orders of thinking: "Instead, the situation in most national and local contexts is of these

different ‘orders’ being mixed up (or churned) together. Therefore, the deficit model co-exists with talk of dialogue and engagement”. Stocklmayer and Rennie (2017) also talk about how informal learning activities, for example at museums and zoos, can encompass a spectrum of engagement from passive to fully participatory. However, the coexistence of the different models has not been fully explored in the literature or included in theorisation of the three models. Nor has it been tested widely against science communication practice.

2.6 Concluding remarks

This chapter has explored the science communication models as they have been theorised by various scholars in depth. The collation and synthesis of scholarly literature about science communication models has not been done to this extent before. The summary of the theorised models (as shown in Tables 1 and 2) represent a framework for investigating the practice of science communication. The theorised science communication models are set against a backdrop of drivers for policy and science communication practice change, especially with the rise of more controversial science.

While some researchers have critiqued these models of science communication using practice examples to point to their inadequacies, few scholars have worked with science communicators to test how well the theorised models translate into practice, especially when the science is controversial. Instead, the scholarly literature on science communication models appears to blame science communicators for their continual reinvention of the deficit model. This is likely to lead to an even greater disconnect between science communication scholars and practitioners. However, with more empirical research on science communication in practice, scholars would be better able to describe and understand science communication in practice, and science communicators would be better able to apply such models to their practice.

There are currently no comparisons of the theorised models with national science engagement programs. The use of relatively new social media tools by science communicators such as blogs has not been tested against the background of the theorised models. And while there has been some scholarly analysis of one-off participatory events like citizen juries, there has been little research focussed on long-term deliberative participatory science communication projects.

My next three chapters, which compose the bulk of this thesis, seek to fill these gaps. In the next chapter, I compare the theorised characteristics of science communication models with the stated engagement practices of a 2012 Australian science engagement audit to determine how the models compare with a wide range of national practice, including at least some engagement activities about controversial science. Chapter 4 looks at two polarised science communicator-initiated climate change blogs to investigate how well this relatively new social media tool reflects the theorised models, especially dialogue. Chapter 5 looks at a long-term participatory climate science communication program, initiated by science communicators, to analyse its characteristics in comparison with those theorised for the three science communication models. These three studies aim to bridge the gaps in our understanding and empirical analysis of the nexus between the theorised science communication models, and the realities of practice.

3. Comparing science communication theory with the science engagement practices recorded in a 2012 Australian audit

3.1 Introduction

The previous Chapter outlined how traditional means of transferring knowledge from scientists to various publics, generally through publications, lectures and exhibitions, has been questioned by those researching science communication, and those in governments and research institutions involved in devising strategies and making policies relevant to science communication. Those scholars describing theoretical models of science communication have called for more interactive and deliberative communication where scientists more actively engage with publics (e.g. Horst & Michael, 2011; Jackson et al., 2005; Kurath & Gisler, 2009; Nisbet & Scheufele, 2009).

With the perceived failure of the deficit model and with scholars concerned about the continual reinvention of the deficit model with dialogue engagement activities, some argue that participatory science communication had the potential to lead towards a much greater democratisation of science, especially with controversial science (Bubela et al., 2009; Joly & Kaufmann, 2008; Miller, Fahy & ESConet Team, 2009).

The theoretical models of science communication describe the relationships between scientists and publics, and to various extents this means examining issues of power, knowledge access, social identity and trust. This Chapter compares the relationships between science and publics that have been theorised in models, as described in the previous Chapter, with the practices of science communication as recorded in a 2012 audit of Australian science engagement activities. Due to the role that public science controversies play in driving demands for new models of science

communication, I was also interested in exploring any differences between controversial and non-controversial engagement activities in practice.

3.1.1 Research questions

This chapter analyses the results of the Australian 2012 survey of science engagement activities with regards to their fit with the three science communication models described in Chapter 2. The questions I sought to answer by investigating the 2012 survey data are outlined below.

- (1) What are the objectives for Australia's science engagement activities, and how well do these reflect the theorised science communication models?
- (2) Does the nature of engagement (who is targeted, what are they doing and how) reflect the theorised science communication models?
- (3) How is engagement different between activities about publicly controversial science compared to non-controversial science?
- (4) How can the empirical study of the practice of science engagement inform the further theoretical development of science communication models?

3.2 The data—2012 National Audit of Australian Science Engagement Activities

This chapter uses some of the raw data that were collected through a 2012 national audit of science engagement activities in Australia, which was conducted for the Federal Government's *Inspiring Australia* program (Metcalfé, Alford & Shore, 2012). I led the project team collecting this data, providing strategic and academic oversight. The audit was the first and last time that data such as this has been collected, and as such, it provides a snapshot in time that can point the way to similar future studies and provide a point for later comparison.

The national audit used an online survey tool (see Appendix A) to collect details of science engagement activities, including information about:

- how much each activity sought to achieve the Inspiring Australia strategy's four outcomes (see p. 44 of this thesis);
- who the activity targeted and involved, including those directing and funding the activity;
- the type of involvement and tools used to engage people; and
- whether the activity was evaluated and, if so, how it was done.

The audit also sought people's views on how science engagement activities in Australia could be improved. Once the survey was drafted, it was reviewed by an informal advisory committee and Professor Martin Bauer at the London School of Economics. The next draft of the survey was piloted with eight activities and then redrafted based on the feedback of the people entering those activities using the online survey tool. The survey was promoted through the ASC email list, Inspiring Australia contacts, other databases of science organisations, meetings, and phone calls. It was promoted to any sector thought to be involved in science communication: universities; cooperative research centres; the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and other nationally funded research centres; medical research and public health centres; local, state and federal government departments; museums and science centres; national parks, botanical gardens and zoos; science communication consultancies; non-government organisations; and community groups. The promotional document is shown at [Appendix B](#).

As an example of an unrestricted survey that anyone could choose to complete, it is not possible to generalise about the data as being representative of the whole Australian science engagement effort. However, the breadth and diversity of

organisations and activities represented in the responses to the survey does mean there is a useful data set of many of the science engagement activities happening in Australia during 2012.

There were 415 activities recorded in the audit by 325 different respondents. Half of the respondents were from universities and research institutes, followed by cultural organisations, including science centres, museums, zoos, art galleries and wildlife centres. Most respondents were from Australia's large cities, which is not surprising given almost 90 per cent of Australians live in an urban area. The majority (52%) of the activities recorded in the audit started or planned to start their activities in the year range 2010–13.

3.3 Methods and results

3.3.1 Science communication objectives

Two qualitative and two quantitative questions in the audit were relevant for determining the likely science communication objectives for each activity. The first of these qualitative questions asked, “What significant issue, need or priority is your activity addressing?”. The second asked, “Can you describe the motivation for the activity”.

I coded the qualitative data using thematic content analysis (Cho & Lee, 2014). I first used a deductive approach to analyse responses against the objectives identified in the literature about science communication models, as outlined in the previous section. I then applied an inductive approach to identify any further objectives, not present in the literature. As can be seen in Table 3, there were three objectives not specifically noted in the science communication model literature. The first one, to promote a particular scientific institution or organisation, is similar to the other promotion objectives. The

second two are under participatory objectives and relate to people participating in the science either jointly with scientists (objective 21) or through a citizen science approach (objective 22).

I coded for all the objectives embedded in each qualitative response; for example, one response about the significant issue, need or priority that an Australian Museum Science Festival activity addressed included eight different objectives (objectives 1, 2, 4, 7, 8, 10, 15 and 20 from Table 3), which was the maximum number of objectives noted for any activity. However, the majority of responses (48% for Question 1; 76% for Question 2) had only one objective. For example, “Engaging the public with the latest scientific research in Chemistry”. Similar objectives emerged for both qualitative questions, however the question about motivations for the activity included additional themes related to the likely success of the activity rather than to motivations for the activity or its objectives. For example, respondents made statements like, ‘worked in the past’ and ‘others had done it before successfully’.

Another independent researcher coded 22 per cent of the data (Lombard et al., 2004 suggests a sample of 10% is sufficient to test intercoder reliability) using a coding guide that I developed. There was 95 per cent agreement between the coded data for the first question, and 97 per cent for the second question, indicating strong intercoder reliability.

The coded results are shown in Table 3. I have listed the objectives under each of the three models in Table 3 in order of increasing interactivity. The objectives that include the motivation ‘to promote’ (objectives 4-7 in Table 3) would be on the same level. This ordering is subjective and based on my understanding, working as a science communication practitioner for more than 28 years, of the likely level of interaction needed between science communicators and various publics for each objective.

Therefore, using my assumptions based on practical experience, the objective ‘to raise awareness’ would require the least level of direct interaction between science communicators and publics, and the objective to ‘to critically reflect on science and its institutions’, the most.

Table 3. Coding of qualitative data in response to asking for the significant issues driving the need for the engagement and the motivation. Codes 1-14 are noted in the literature as being associated with the deficit model. Codes 15-20 reflect dialogue models, and codes 21-28 reflect participatory models. Note objective 12 fits under both deficit and dialogue objectives in the literature. (Those codes shaded in grey were deduced from the data rather than from the literature.)

Code	Definition	% in Q1: issue addressed (N=403 valid responses)	% in Q2: motivation for activity (N=207 valid responses)
Deficit model objectives			
1	To raise awareness	14.3	6.7
2	To transfer information	26.5	12.5
3	To correct misunderstandings of misperceptions	1.9	1.9
4	To promote or gain support for science / scientists	11.6	4.8
5	To promote or gain funding for science	3.2	0.5
6	To promote a particular scientific institution or organisation	1.9	7.7
7	To promote science as a career	18	12.1
8	To inspire, build excitement, generate interest in science	16.1	16.9
9	To explain or increase understanding	9.1	5.3
10	To educate or increase learning	13.6	13
11	To respond to people’s interest in science	0.2	2.9
12	To address people’s concerns about science and increase trust in science and scientists	0.3	0.5
13	To influence people’s attitudes	3.5	1.4
14	To influence people’s behaviour	5.9	3.8
Dialogue model objectives			
15	To be or to make science / scientists more accessible	24.5	16.4
16	To find out public opinion or about audience needs	0.7	1.9
17	To gain lay knowledge	1.2	0.5
18	To debate / discuss scientific / technological issues	3.5	2.4
19	To help people to make decisions	2.5	4.3
20	To make connections between people, including between disciplines	4.4	3.4
Participatory objectives			
21	To participate in a research endeavour with scientists	4.2	0.9
22	To get lay people involved in gathering data / doing research	1	2.9
23	To participate with other interests to influence the culture of science in society	3.4	0.5
24	To participate in democratic policy making	2.2	4.3
25	To collectively learn, reflect, solve problems	1.7	1.4

Code	Definition	% in Q1: issue addressed (N=403 valid responses)	% in Q2: motivation for activity (N=207 valid responses)
26	To shape the agenda of science	0	0
27	To coproduce new knowledge / products	0.2	0
28	To critically reflect on science and its institutions	0	0

The objective to simply transfer information is the most common for question 1 (26.5%) about the significant issue the activity is addressing, and third most common for question 2 about the motivation for the activity (12.5%). A typical response was, “Distribution of science information to community”. The top response (16.9%) when asked about motivation (question 2) and the third most popular response for question 1 (16.1%) was ‘to inspire, build excitement, generate interest in science’. Typical responses were: “Engaging community members with the natural world around them and encouraging a creative approach to viewing nature”; and “The need to engage children in excitement and enjoyment of science”.

The second most common response for both questions was “to be or to make science/scientists accessible”. This included responses like: “The talks series we hold allow members of the general public to hear and chat with practicing leaders in Australian science”; and “The South Australian Museum, as a fair and equitable institution, is compelled to support remote communities to access the SA Museum, one of the state’s key science communicators”.

More than one third of all activities (33%) for question 1 and one quarter (25%) for question 2 listed at least one of the objectives related to promotion (objectives 4-7 in Table 3). The objective ‘to promote science as a career’ was particularly dominant. For example: “The need to encourage more young people to enter engineering by showing them the changing face of technology in that area”.

Other common objectives were to ‘increase awareness’, ‘educate or increase understanding’, and ‘to explain or increase understanding’. As can be seen, deficit-style objectives dominated most activities. With the exception of the objective to make science / scientists more accessible, all other dialogue objectives were represented in less than five per cent of the activities for both questions. Likewise, very few activities described participatory objectives. There were no activities that had the objectives to ‘shape the agenda of science’ or to ‘critically reflect on science and its institutions’.

Most activities coded as having only deficit-style objectives (60.5% for question 1; 61.4% for question 2). The next most common objectives that activities reflected were a combination of deficit and dialogue (16.1% for question 1; 7.7% for question 2), or just dialogue objectives (13.1% for question 1; 17.8% for question 2). Activities reflecting participatory objectives tended to be only about participation (2.7% for question 1; 8.2% for question 2) or were in combination with deficit objectives (3.7% for question 1; 2.9% for question 2). Very few activities had objectives spanning all three models (1.5% for question 1; 0.9% for question 2).

The first quantitative question asked respondents to rank the four outcomes of *Inspiring Australia* strategy that they wished to seek from their activity from high importance (1) to low importance (5). These four outcomes (Australian Government, 2010, page xiii) are:

- (1) a society that is inspired by and values scientific endeavour;
- (2) that attracts increasing national and international interest in its science;
- (3) that critically engages with key scientific issues; and
- (4) that encourages young people to pursue scientific studies and careers.

Achieving the first and second outcomes would likely result from activities that reflect objectives coded 4, ‘to promote or gain support for science / scientists’ and 8, ‘to

inspire, build excitement, generate interest in science’ in Table 3. The fourth outcome matches with objective 7, ‘to promote science as a career’. All of these three outcomes are therefore achieving deficit model objectives. Outcome three could result from dialogue objective 18, ‘to debate / discuss scientific / technological issues’ and / or participatory objective 28, ‘to critically reflect on science and its institutions’.

The most important outcome for the majority of activities (30%) was the first outcome above, ‘a society that is inspired by and values scientific endeavour’, which corresponds with the qualitative data showing that many activities were motivated by the need to inspire people with science or promote science in some way. The fourth outcome (22%) of young people being encouraged to pursue scientific careers was the next most highly rated, which again corresponds with the qualitative data, which showed that many activities were about promoting science as a career. The third outcome (19%), of a society that critically engages with key scientific issues was also seen as important, although the qualitative data shows few activities were about debating or discussing scientific issues, and no activities were motivated by ‘critically reflecting on science and its institutions’. Interestingly, the second outcome of a society that ‘attracts increasing national and international interest in its science’ was seen to be the least important (14%) by respondents, despite this outcome being about attracting interest in science, and therefore promoting science. ‘Other’ outcomes (15%) chosen by respondents included changing opinions or behaviours.

The second quantitative question asked what each engagement activity focused on and provided five options that respondents rated them as being (1) a major component of the activity down to (5) not present in the activity, as shown in Table 4. I matched the possible objectives (from Table 3) with the focus of the activity, as seen in

Table 4. The results show that the focus of most activities had a deficit perspective, with far fewer activities having a participatory focus as a major part of their activity.

Table 4. Audit results showing the focus of each engagement activity according to five choices

Focus of engagement activity	Possible matching objectives from Table 3	% rating it a major component of the activity (1 out of 5)	Mean rating where 1 = major component and 5 = absent from activity
Understanding natural and human-made world	9	29.8	2.04
The nature of the scientific process or enterprise	4, 9	22.4	2.27
Societal and environmental impacts and implications from science and technology	18	20.3	2.29
Personal, community and societal values related to applications of science and technology	16, 17, 18, 19	19.9	2.39
Institutional priority or public policy change related to science and technology	26, 28	7.5	3.81

3.3.2 Nature of engagement

The audit also investigated how respondents described the activity: who was targeted by the engagement; and the methods used to engage their target groups. The answers to these questions help to better understand the nature of the engagement, which means we can explore further the practical application, or not, of the theorised science communication models.

I analysed respondents' own description of their activity (a qualitative answer to the online audit survey) using a similar thematic content analysis that I used with the other two qualitative questions, as described above. However, with the respondents' descriptions I used only an inductive approach where the codes were revealed entirely by the data. Each response could generate multiple codes. My coding was tested against that of another independent researcher who coded 22% of the data. There was a 95% agreement between the coding, indicating a high level of reliability.

I attempted to match the coded descriptions with the likely objectives coded for in the first two qualitative questions (see Table 3). As can be seen in Table 5, activities that could assumed to be more deficit-style still dominate. Holding events of some kind was the most likely description (36%) to be included at least as part of an activity. While such events are most likely a response to objectives, which aim to inspire and build excitement for science, such undertakings are likely to reflect a complexity of ambition. For example, one respondent wrote, “Running informal science parties for groups of children aged 4 to 14.” When looking at the coded objectives for this activity, they were also deficit in nature: “That science literacy doesn't need to be gained from formal settings”; and “We run this activity to inspire the general public to pick up science”.

Despite these described objectives, given the informal setting, it is likely that this event did include some form of interaction and discussion. Another respondent wrote, “For National Science Week 2012 we are building a giant cellulose molecule using origami. The public are invited to fold origami ‘atoms’ and learn about the cellulose and polymers at the origami folding sessions in Perth in August”. The significant issue driving this event is described as, “To encourage participation in science and generate and maintain excitement about the benefits of science to our society. To increase awareness of the importance of polymer research.” This event, while predominantly deficit in nature, also included hands-on activities that would involve dialogue and interaction between the public and science communicators.

Table 5. Coding of qualitative data in response to a question asking for a brief description of the engagement activity

Code	Description	Possible matching objectives from Table 3	% N=411
0	Describes only a research activity, not an engagement activity	N/A	3
Deficit-style activities			
1	Produce a publication	2	7
2	Orally present science (one-way communication from someone/media to audience)	1, 2, 3, 8, 9, 10	12
3	Use traditional means of mass media – print, TV, radio to engage	1-9, 13, 14	2
4	Provide an award to people	4, 6, 7	4
5	Put up a display / exhibit	1- 4, 6, 7, 9	9
6	Have a promotional strategy/campaign	4- 7	2
7	Use formal educational means to engage	10	17
8	Use online means to communicate including website, social media	1-9, 11-14	10
9	Hold some type of event / show / meeting	8, 11	36
10	Compete for a prize	8, 11	5
Dialogue-style activities			
11	Have an activity that involves people in science / with scientists	15	26
12	Give people access to science, scientists, science resources	15	14
13	Train / help develop people's skills, so they can communicate better / participate in science	15	6
14	Hold a workshop	17-20	10
15	Bring people together into a network	20	4
16	Discuss science / scientific issue	18	8
17	Bring together people from different disciplines or areas to work together	20	6
18	Research / find out about people's opinions and needs to better engage / communicate with	16	2
Participatory-style activities			
19	Lay people participate with scientists in an activity	21	1
20	Lay people collect data or actually do research	22	6
21	To jointly produce new knowledge/ products	27	0.5

A significant proportion of activities included involving people with an activity involving people in science or with scientists (26%) or providing access to (14%) scientists or science (coded as 11 or 12 in Table 5), which supports the notion that there are at least some dialogue interactions happening between scientists and the public in the activities recorded. For example,

Specific programs targeting adult audiences who wouldn't normally attend the museum. All programming is diverse, eg. SmartBar at Melbourne Museum and Big

Kids' Night Out at Scienceworks - licensed after hours event where talks and demonstrations are given by museum scientists in a casual setting.

This activity is providing access to scientists and science resources that the public normally would not have. Another example demonstrates where scientists interact with students during a hands-on activity, "Hands-on biotechnology workshop for senior secondary students. Lab activities on basic molecular biology with research examples of how biotech is used in agricultural plant science." The majority of activities (40.3%) described reflected a mix of deficit and dialogue characteristics. However, almost the same proportion of activities (39.8%) reflected only deficit characteristics.

There were very few participatory-style activities recorded other than those related to citizen science where lay people collect data or do research (6%). There were only two recorded activities where scientists jointly produced new knowledge or products with the public. However, in both these examples scientists or science communicators still play the dominant role in the engagement,

With community and student teams we will (1) undertake test-excavations and collect sediment cores at both sites, (2) collect samples for dating (using advanced techniques not available in previous investigations), (3) recover buried biotic remains (pollen, charcoal) for subsequent identification, (4) assess site formation processes, and (5) review oral and written records. We work with community members in the application of these techniques and together develop an interpretation of landscape change and site use in the recent (c.1800-1900 AD) and the distant past (as much as 19,000 years ago). This approach helps people appreciate the varied time-scales involved in the historical sciences and the array of techniques that a field project may use. In turn this knowledge will help the community apply archaeological research tools and frameworks for the benefit of local heritage and culture.

Science theatre company Teacup Tumble will create a new half-hour physical theatre work using content generated by a creative development process with teenagers from the Bendigo region. Over four creative development sessions, we will use geometry of two- and three-dimensional space as a starting point for exploring maths from an artistic angle.

The work will then be performed four times over two days at venues easily accessible and convenient to our target audience.

Eight activities (2%) included only participatory characteristics in their descriptions. Seven of these activities were about citizen science, for example Reef Watch is described as a “Citizen science environmental monitoring program that engages people in science using their interests. It brings recreational divers together to gather information and gives them scientific skills”. Only 11 activities (2.7%) included characteristics from all three models in their activity descriptions. Most of these include citizen science along with other activities. For example, the Herdsman Lake Frog Fest is described as “a frog talk, activities, a sausage sizzle & nightstalk through the wetland; the participants learn the calls and appearance of local frog species and then conduct a survey, spotlighting for frogs and other animals from the boardwalk, and recording the information collected as part of the Tronox Nightstalk”.

Some of the respondents (3%) only described the research they were doing rather than a specific engagement activity. For example, “Undertaking research & development for the benefit of Australia's services sector”, and “Research into stress associated with disability in the university students, young children transitioning into school etc”.

I compared the model coding for all three qualitative questions: significant issue addressed, motivation for activity and description of activity, as can be seen in Table 6. Across all three questions, the most common combination (55.7%) was activities coded as reflecting a mix of deficit and dialogue characteristics. This was followed by deficit only (26.9%), and then activities with characteristics that reflect all three models (10.6%). As can be seen in Table 4, when you look at the characteristics of activities across *all* qualitative answers, you are much more likely to discover a mix of science

communication characteristics present in the activities. This is particularly true for activities reflecting deficit plus dialogue, and for those that reflected all three models. Interestingly, participation model characteristics are more likely to be linked with deficit model characteristics (4.3%) than with dialogue (0.9%). No activities had only participation characteristics across all qualitative responses. Responses to the question asking for a description of the activity are more likely to generate a mix of model characteristics than those asking objective-related questions. Comparing the coding of all qualitative responses indicates that most activities have at least some deficit model (97.6%) and dialogue (68.8%) characteristics. However, relatively few activities (15.9%) describe participatory model characteristics or objectives.

Table 6. Coding of all qualitative data according to the science communication models present

Model coded	% for question on significant issue addressed (N=403)	% for question about motivation for activity (N=207)	% for question asking for description of activity (N=402)	Total across all questions (N=413)
Deficit only	60.5	61.4	39.8	26.9
Dialogue only	13.1	17.8	11.9	1.4
Participation only	2.7	8.2	2.0	0
Deficit and dialogue	16.6	7.7	40.3	55.7
Deficit and participation	3.7	2.9	2.2	4.3
Dialogue and participation	1.7	0.9	1.0	0.9
Deficit, dialogue and participation	1.5	0.9	2.7	10.6

The nature of science engagement is also determined by who is targeted by an activity. Respondents to the audit were asked to select target groups for their activity from a list. Most activities targeted mass audiences such as school-aged children, the general public, and metropolitan and regional communities. Far fewer targeted specific groups such as policy makers, politicians, business leaders or farmers.

Audit respondents were asked a quantitative question about how the target groups were involved in the engagement activity and were given five options where

they rated whether that type of involvement was a major component (1) or not part of the activity (5), as shown in Table 7. I matched how target groups were involved with the objectives in Table 3. As can be seen, deficit and dialogue-style methods of engaging target groups dominate, and participatory-style activities are far less likely to be used to involve target groups in activities.

Table 7. Audit results showing how target groups were involved in each engagement activity according to five choices (As per Table 1, objectives 1-14 match with deficit model; objectives 15-20 with dialogue, and objectives 21-28 with participation)

How target groups were involved	Possible matching objectives from Table 3	% rating it a major component of the activity (1 out of 5)	Mean rating where 5 = major component and 1 = absent from activity
Learning from watching, listening, viewing lectures, media and / or exhibits	2, 3, 9, 10, 11	34.4	4.0
Asking questions of experts, interactive inquiry learning in activities / exhibits	10, 11, 15, 18	32.6	3.9
Consulting, sharing views and knowledge between participants and science experts	17, 18, 20, 25	16.5	3.0
Deliberating with other participants and group problem-solving	24, 25	11.4	2.6
Producing recommendations or reports	27	5.1	1.6

3.3.3 Comparing controversial and non-controversial activities

I categorised the descriptions given by audit survey respondents as being about publicly controversial or non-controversial science. Controversial science was deemed to be any activities focused on topics such as climate change, other environmental issues, nanotechnology, biotechnology, genetically modified food and stem cell research. These are the publicly controversial issues in the Australian media (Ankeny & Dodds, 2008; Harwood & Schibeci, 2008; Hindmarsh & Du Plessis, 2008). Only 44 (11%) activities were about controversial science issues with most of these (32) being about climate or other environmental issues such as conservation of the Great Barrier Reef. This reflects the dominance of environmental issues being debated publicly in Australia

(Carson et al., 2010; Bacon, 2013; Speck, 2010). An example of a typical controversial activity was:

The Institute maintains a strong relationship with climatologists, agricultural scientists, and health, energy, and assorted other researchers in Australia and elsewhere in an effort to ensure our communications and policy work is scientifically informed, and there are expert voices in the climate policy debate.

I found some differences when comparing controversial and non-controversial activities. For the *Inspiring Australia* strategy outcomes, respondents involved in activities about controversial science were far more likely to want to ‘critically engage target groups with key scientific issues’ and were less likely to be concerned about the other three outcomes. When looking at the focus of activities, respondents reporting on activities about controversial issues were far more likely to say their activities focused on ‘societal and environmental impacts and implications from science and technology’ than respondents for non-controversial activities. On the other hand, respondents for non-controversial activities were far more likely than those for controversial activities to focus on ‘the nature of the scientific process or enterprise’. When looking at how target groups were engaged in the activities, respondents for controversial activities were much more likely than those for non-controversial activities to involve their groups by ‘deliberating with other participants and problem-solving’, and by ‘producing recommendations or reports’. This provides at least some empirical evidence that science communicators approach engagement activities about controversial issues in different ways to activities about non-controversial topics.

When comparing controversial activities using the coded qualitative data, a quarter (25%) of respondents included characteristics of all three models in their responses to the three questions. This is more than double that for the whole data set (10.6%). A much higher proportion (38.6%) of controversial activities are also likely to

reflect at least some participatory model characteristics across the three questions compared to the total coded data (15.9%). Interestingly, all controversial activities include deficit model characteristics in the qualitative responses.

3.4 Discussion

3.4.1 Objectives for engagement activities broadly reflect theorised models

Australia's science engagement activities, as recorded in 2012, appear to include objectives that broadly fit those theorised in the deficit, dialogue and participatory models. Most scholars discussing the deficit model emphasise objectives related to information transfer and education to ensure science literacy. While information transfer was important for about a quarter of the engagement activities recorded and education for 13 per cent, more than one third of Australian engagement activities were focussed on the promotion of science, especially the promotion of science as career. The *Inspiring Australia* outcome that most respondents (30%) to the survey ranked as being the most important to their activity, 'A society that is inspired by and values science', also reflects the promotional aspirations of respondents. While some scholars recognise that deficit and dialogue science engagement activities may be done to legitimise science rather than disseminate or converse about science, there is less explicit recognition of science communicators' desire to promote science and its institutions. An exception to this is Trench (2008, p. 133), who recognises the role of marketing where "the purpose is to persuade the public... perhaps by promoting successful scientists as role models".

Another difference between theorised objectives and those that emerged from the data is the desire of some science communicators to involve lay people in a research endeavour with scientists and / or get some lay people involved in gathering data or

doing research. The later objective in particular, which is core to citizen science activities, has been largely ignored in scholarly discussions about science communication models to date. However, citizen science activities are expanding worldwide and there are international and national associations for citizen science and regular conferences about the topic, which include discussions on science communication. In late November 2016, the Australian government announced funding for citizen science grants of between A\$50,000 and A\$500,000 as part of the *Inspiring Australia* science engagement programme. The aim of the grants is “to provide opportunities for the public to engage in science by participating in scientific research projects that include the collection or transformation of data in Australia” (Australian Government, 2018). As a result, it is very likely there would be even more citizen science activities in Australia now compared to five years ago.

3.4.2 Australia’s science engagement dominated by deficit and dialogue objectives and activities

Trench (2006) posed the question, “how dead is the deficit model”. The results of the audit demonstrate that it is alive and well in Australia. The majority of all engagement practices recorded in the audit reflect at least a few of the objectives and activities typical of deficit-style communication. The most common deficit-style objectives from the qualitative data were to ‘transfer information’ and to ‘inspire, build excitement and generate interest in science’. Responses to quantitative questions backed up this finding. For example, when looking at what the activities focussed on, ‘understanding the natural and human-made world’ was a much more important focus for science communicators than ‘public policy change’. The two described deficit-style activities that dominated the qualitative data were to hold some type of event, show or meeting, or to orally present science through a person or using a media format. This corresponds

with the quantitative question about how target groups were involved in the engagement activity where ‘learning from watching, listening, viewing lectures, media and / or exhibits’ dominated the responses.

However, when looking across all qualitative and quantitative responses, it is clear that most activities feature deficit-style activities and objectives in combination with dialogue. This is particularly true for dialogue objectives and activities at the lower interaction end of the communication spectrum. For example, making science or scientists more accessible was by far the most common dialogue objective coded in the qualitative data. Given that over a third of respondents described their activity as some type of event, show or meeting, it is not surprising that there would be at least some level of two-way interaction between science communicators and publics.

The two dialogue-style activities that dominated were those that involved people in science or with scientists, and those that gave people access to science, scientists and science resources. Every other dialogue objective was found in less than five per cent of responses. Very few activities were about discovering public opinions and needs of science; gaining lay knowledge; debating or discussing science and technology issues; helping people make decisions; or making connections between people of different backgrounds and disciplines. These findings may correspond with scholars postulating that the motivation for many dialogue activities is to increase the understanding of and hence the acceptance of the science rather than open it up to public scrutiny or input (Irwin & Wynne, 1996; Trench, 2008).

There were no activities where all the objectives and descriptions were only focused on the participatory model. Each participatory objective featured in less than five per cent of activities. There were no activities coded where target groups shaped the agenda of science or critically reflected on science and its institutions. This is of

concern given the value of such activities for science and its communication (Irwin, 2008). Interestingly, in response to the quantitative question about *Inspiring Australia* outcomes, almost one fifth of respondents said critically engaging target groups with key scientific issues was important to their activity, and yet the objective to ‘critically reflect on science and its institutions’ did not emerge in any of the qualitative data. These results suggest that respondents like the idea of this outcome, but do not focus on it when explaining their engagement activity. As such, it is unlikely to be an actual feature of many of the engagement activities described in the audit. The only substantial participatory activity (6%) involved lay people collecting data or actually doing research.

The paucity of participatory activities, which usually involve smaller concerned groups, is reflected by the fact that most activities recorded in the audit targeted mass groups, such as school children and the general public. Targeting mass publics is more typical of deficit-style communication where one-way communication is more efficient and feasible (Jensen & Holliman, 2015). One-off participatory engagement activities such as citizen juries also aim to have a representative selection of the general public. However, longer-term participatory activities are more likely to focus on specific groups of citizens concerned about a particular issue, and less of this appears to be happening in the audit’s activities. Scientists and their organisations still appear to control and dominate engagement activities, which is typical of the science-public relations of the deficit and dialogue models compared to the highly interactive and personal engagement theorised for participatory models of science engagement (Bubela et al., 2009; Irwin & Wynne, 1996; Joly & Kaufmann, 2008).

3.4.3 Engagement activities around controversial science more likely to be deliberative and participatory

Given the degree of controversy in Australia over climate change and other related environmental issues, it is surprising that the audit did not uncover more engagement activities focussed on these areas. Perhaps this reflects the lack of resources for such time-intensive activities and science communicators' own aversion to communicating complex controversial topics versus objective facts (Jensen & Holliman, 2015).

The small sample size of engagement activities coded as being about controversial science means that any comparisons between these activities and the full data set are limited in their interpretations. However, both the qualitative and quantitative results do indicate that activities about controversial science are more likely to reflect participatory objectives and activities than the full data set. Target groups involved in such activities are far more likely than those involved with non-controversial science to be deliberating about the science and working with science communicators to problem-solve and produce joint recommendations and reports. These findings reflect the contention of some scholars (Callon, 1999; Trench, 2008) that participatory means of engaging people in science are particularly suited to activities around controversial science issues.

3.4.4 Analysis of practice can further develop theoretical considerations of science communication

In analysing the results of the audit in the context of the three science communication models, it is clear that engagement in practice happens along a spectrum from raising awareness about science at the start of the deficit model through to critically reflecting on science and its institutions at the far end of the participatory model. My research into the audit activities' objectives, descriptions, and differing involvement of various

groups indicates that there is no clear separation between the three models in practice; instead there is a large degree of overlap of objectives and activities that can be described across the three models. Most activities reflect a combination of at least deficit and dialogue objectives and activities. This finding was also reflected in Brossard and Lewenstein's (2010) case study analysis of Human Genomic outreach where they concluded that "Projects tended to use mixed approaches that blended models, rather than gravitating to any one framework". Likewise, Jensen and Holliman (2015) found that science communicators often include aspects of more than one order of thinking when describing public engagement.

This analysis of the national audit's science engagement activities indicated that most dialogue and participatory style activities happen alongside at least some deficit-style communication activities. For example, my analysis of the audit data showed that no participatory activities were only about participation; they also included dialogue and especially deficit objectives and activities. Brossard and Lewenstein (2010, p. 32) found the same thing in their analysis of practice, "All outreach projects tended to use the Deficit Model approach as a backbone, even if they seemed to follow other theoretical approaches." This could possibly indicate that more deliberative activities, like those theorised for dialogue and participatory science communication models, are built upon or even rely upon the theorised deficit style approaches to science communication. This will be explored further in the next two chapters when the thesis compares the theorised science communication models with a dialogue example and a participatory practice example.

Instead of throwing the deficit model out, scholars would do well to look at how such activities in practice support and link with dialogue and participation activities. Bucchi (2008) identified the probable overlap between science communication models

when he noted that “Most communicative situations would be described by a combination of the three models”, but this notion has not been deeply explored by scholars. Instead, a strong rhetoric of three distinct and evolving models of science communication still prevails (e.g. Höppner, 2009; Palmer & Schibeci, 2012; Stocklmayer, 2013).

My empirical analysis of the audit activities expands on the framework posed by Bucchi (2008) that identifies, like many other scholars, only one aim for each of the models: deficit – transferring knowledge; dialogue – discussing implications of research; and participation – setting the aims and shaping the agenda of the research. These are perhaps overarching aims for the three models, but my research identified a spectrum of likely objectives for each model from the collation and synthesis of the scholarly literature, which is also reflected in practice.

Scholars developing or examining science communication models have not commonly discussed many of the objectives coded in the audit data. For example, there is little discussion of the objective to ‘promote’, which refers to activities whereby science communicators seek to promote a particular brand of science, a career in science or a scientific organisation or program. While van der Sanden and Meijman (2008) do talk about ‘promotion’ when they compare science communication with health communication, very few other scholars focus on or explore promotional science communication objectives.

Providing publics with *better access* to scientists, science information, networks, support, and skills development is another objective that emerged commonly from the audit activities. With few exceptions, this is also little discussed by scholars in the academic literature. Guston (2014) does talk about the need for ‘capacity building’ of publics so they are capable of engaging with scientists in the USA Center for

Nanotechnology in Society at Arizona State University. Capacity building is a similar notion to providing publics with better access. In the same context, Selin et al. (2017) suggest that “the notion of *capacity building* might be a way of reframing the democratic potential of public engagement with science and technology activities” (p. 634-635). Achieving a capacity building or access objective means it is presumably easier for publics to then engage with scientists and science. This could be an early step or even a prerequisite for more sophisticated dialogue and participatory activities.

My analysis of practical engagement activities indicates that science communication scholars could examine further the rich spectrum of objectives and activities that lie from one end of the deficit model through to the end of the participatory model, where there is considerable overlap between the three models. More research on the objectives for, the focus and the style of target group involvement in engagement activities could lead to further evolution of these models, especially when considering the communication of controversial science. Such research can gather richer data from practitioners when it uses open-ended questions asking respondents to, for example, describe their activity, rather than respond to specific quantitative questions.

3.5 Conclusions

In summary, my research analysing the audit, showed that when all the predicted objectives and characteristics of science communication models are taken together, they do appear to represent the breadth of motivations and characteristics that are there in a national audit of science engagement practice. However, my analysis also shows that most activities include a mix of the predicted deficit and dialogue models, and occasionally participatory motivations and characteristics. This indicates there are no distinct boundaries around the three models in practice. This may be unintentional on

the part of the science communicators initiating the engagement activities, as this mix of model characteristics was only deduced when analysing all their audit responses, rather than relying on responses to just one question. However, it is also possible that one style and mode of science communication needs to also incorporate the other to help it work; for example, dialogue techniques of science communication may rely on deficit techniques, and participatory may rely on both deficit and dialogue techniques.

Bucchi (2008, p. 68) talks about how the funding and policy initiatives in many countries have “shifted their keywords from ‘public awareness of science’ to ‘citizen engagement’; from ‘communication’ to ‘dialogue’; from ‘science and society’ to ‘science in society’”. The demand for more direct public engagement in science has risen even further in the decade since Bucchi made this statement, as manifest in Australia with national strategies such as *Inspiring Australia*. However, this rhetoric has not yet been translated into practice with most of the activities recorded in the audit appearing to be motivated by a desire to either transfer information, generate excitement and interest, or promote science, science institutions or science careers. This continues to reflect the 1888 establishment objective of the Australian Association for the Advancement of Science to primarily “promote science in Australia” (Burns, 2014, p. 73). Modern science communication in Australia is likewise focused on promoting science, whether that be a brand of science, a scientific institution or a career in science.

In practice, often those applying the deficit model of science communication are preaching to the converted; to those already interested and engaged in science (Nisbet & Scheufele, 2009). It would appear that many of the activities recorded in the Australian audit fall into this category. While there is nothing wrong with engagement activities directed to the already converted, there is clearly a gap in reaching those not engaged. Bucchi (2004) talks about the failure of science communication that is science literacy-

driven given that many studies have shown, for example in the biotechnology arena, that increasing communication with the public did not “reduce significantly the likelihood of [the public] being hostile to certain biotechnology application” (p. 270). There is still an assumption by many that science literacy is both the problem and the solution to societal debates and conflicts (Nisbet & Scheufele, 2009).

With the increasing focus of the Australian public on controversial science, it is clear that more efforts need to be made to engage various publics through more deliberative dialogue and participatory activities. This is not to say that deficit activities should be abandoned, nor is it to say that deficit activities are not useful. As already discussed, deficit activities appear to be an important component or even a prerequisite for dialogue and participatory activities. Rather, I am saying that Australia needs to explore and invest in other types of engagement activities if it is to be able to deal genuinely with the contemporary issues it faces. All of the activities recorded in the audit were sponsored and driven by organisations usually involved in or associated with science. Public participation in science, if it is to reach its true democratic potential, should be driven at least in part by various publics and not just by scientific institutions or governments (Bucchi & Neresini, 2008). Interestingly, the audit’s few participatory activities were focused on citizen science or scientists interacting with publics on specific projects. This is in contrast with the literature where participatory science communication is seen to provide the democratic opportunity for publics to participate alongside scientists in deliberating about issues or problems, including the critical review of science and its institutions. Public activism could play a very important role in initiating more participatory science communication. This has not happened in Australia to any real extent, and it would be interesting to investigate why not, given the rise of publicly controversial science. One possible reason is that participatory science

communication, which is “multi-directional, open-ended and potentially open to conflict” (Bucchi, 2008, p. 70), requires scientists and their institutions to relinquish at least some degree of control and power over the communication process.

Irwin (2014) discusses the need for a ‘third order thinking’ about science engagement that puts science-public relations in the wider context to “open up fresh inter-connections between public, scientific, institutional, political and ethical visions of change in all their heterogeneity, conditionality and disagreement” (Irwin, 2014, p. 169). Similarly, Broks (2006) calls for a new perspective that he labels as the ‘Critical Understanding of Science in Public’, or CUSP. In this perspective, science communication: happens in many directions; recognises the social, political and cultural contexts in which it occurs; encompasses knowledge (including values and opinions) from both lay and scientific experts; and is concerned with meanings rather than informational content. Both third order thinking and CUSP require large cultural changes in the mindsets of our scientists, science communicators and the institutions they work for. They also require engagement activities that span, and include, the full spectrum and complexity of the deficit, dialogue and participatory science communication models.

The next chapter looks specifically at an example of dialogue communication about a controversial science issue, climate change. It seeks to explore in more depth how an increasingly common dialogic technique, blogs, engages publics in controversial science. In particular, how are commenters engaging with each other in blogs and how does their engagement reflect the theorised science communication models.

4. Engaging laypeople in a dialogue about controversial science using blogs—A climate change case study

4.1 Introduction

In publicly controversial science fields, like climate change, there is often widespread confusion and misunderstanding about the science (Kahan et al., 2012; Schmidt, 2008). Most laypeople people, defined as those who are not recognised scientific experts, cannot easily access scientific papers online. And, even if they can access these papers, they are unlikely to understand them or the scientific culture that surrounds them. Deliberation through dialogue is thought by some (e.g. Collins & Nerlich, 2014; Niemeyer, 2013) to help make climate change more tangible.

In contrast, communicating climate science through mainstream traditional media outlets represents one-way communication from scientists or science communicators to the lay public. There is rarely an opportunity through traditional media for scientists or journalists to engage directly in a dialogue with laypeople (Colson, 2011; Trench, 2012; Wilcox, 2012). Media researchers (e.g., Bell, 1994; Boykoff & Boykoff, 2007; Carvahlo, 2007; Carvahlo & Burgess, 2005) have shown that traditional media have failed to adequately report on climate change and that “news media often frame climate change mitigation as a dynamic and contested issue within intersecting realms of policy, science and the public” (Swain, 2012, p. 162). As a result, policy makers and science communicators have called for a more deliberative engagement of the public in climate change science and policy, which will likely require dialogue as a starting point rather than the transmission of information through tools like traditional media.

Scholars have postulated that dialogue communication can: help explain complex science (Wynne, 2006); encourage discussion and debate of scientific issues (Bucchi, 2008; Kurath & Gisler, 2009; Irwin, 2008; Scheufele, 2014); and can engage laypeople more democratically in science and technology issues, including making decisions and formulating policies (Kurath & Gisler, 2009; Palmer & Schibeci, 2012; Stocklmayer, 2013; Scheufele, 2014). It is against this background that blogs (defined as informal web pages written in a conversational format) appear to offer potential for climate scientists to engage directly with laypeople to explain their science and answer their questions.

This chapter further tests the characteristics of theorised science communication models, especially the dialogue model, against practical examples of science communication, in this case the people who comment on climate blogs. In this chapter, I explore climate change as an example of controversial science, and what that means for the predicted objectives and characteristics of science communication models and the practice of science communication.

4.2 The potential of blogs to create a dialogue on controversial science

Much has been made of the potential of social media, including blogs, for laypeople to have more of a voice in contested science issues and the media agenda (e.g., Brossard, 2013; Jaspal et al., 2012; Jenkins, 2006; Marres, 2007). For scientists and science communicators blogs appear to offer a medium, which may provide a more expansive space for the democratic deliberation of science with various publics (Brossard, 2013). A review of the literature identifies seven benefits of blogs for communicating with and engaging people in science, especially controversial science. They can (ideally):

- (1) offer the previous consumers of media the opportunity to become the producers of content (Rosen, 2006);
- (2) transform news from being a one-way dissemination of information and opinion to a dialogue where different views are heard and (ideally) valued (Cahill & Ward, 2007; Jenkins, 2006; Meraz, 2011; Schäfer, 2012; Wilcox, 2012);
- (3) amplify the voice of publics by allowing them to participate in scientific debates alongside traditional media, government and science (Cahill & Ward, 2007; Carvalho, 2010; Trench 2012);
- (4) bypass the framings of scientific reporting by the mainstream media, allowing publics to access a broader range of perspectives on scientific controversies (Colson, 2011; Schmidt, 2008);
- (5) offer the opportunity for publics interested in science to explore the complexities of science and to use sources of information and news outside of traditional mass media (Lemonick, 2010; Readfearn, 2010; Schmidt, 2008; Ritson, 2016; Trench, 2012);
- (6) enable scientists, journalists and science communicators to explain the scientific contexts behind the news (Bell, 2012; Colson, 2011; Swain, 2012); and
- (7) transform and complement the peer review process, especially after publication, though informal feedback (Brossard, 2013; Riesch & Mendel, 2013; Ritson, 2016; Trench, 2012; Yeo et al., 2016).

The first four of these seven potential benefits of blogs point to motivations directed at the greater democratisation of science for any publics that can be engaged. The last three point to those publics who are already interested and engaged in science being able to explain, explore and give feedback about the complexities of science in more depth.

The ability of blogs to generate conversations, facilitate interactions and bring together diverse sources of information (Shanahan, 2011) indicates opportunities for a dialogue between scientists, science communicators and laypeople. Blogs provide a means for people to connect rapidly, casually and interactively about scientific information and controversies (Schmidt, 2008; Trench, 2012; Wilcox, 2012). As such, blogs have the potential to move from deficit-style communication to the theorised dialogue model of science communication (Wynne, 2006; Trench, 2008; Zorn et al., 2012), where there is a two-way interaction between scientists and laypeople.

Certainly, the climate science debate, along with controversy about mitigation and adaptation policies and actions, makes for a rich ‘blogosphere’ (defined as all the blogs on a specific topic, and their interconnections) where climate science proponents and deniers are seen regularly online participating in social media (Schäfer, 2012). This was particularly evidenced during and after the 2009 “Climategate” where the battle between IPCC scientists and deniers was carried out almost entirely in blogs (Trench, 2012). It is virtually impossible to count the total number of blogs addressing climate change. Elgesem et al. (2015) studied the texts of 1.3 million blog posts from 3,000 English-speaking climate blogs, which they identified from crawling Wordpress and Blogspot blogs.

The study in this chapter builds on existing research about those who post science blogs (known as bloggers) and the content of their blogs (e.g. Riesch & Mendel, 2013 who researched the distinctive norms of the UK ‘badscience’ blog communities). Scholars have identified a variety of motivations for people to engage in science blogging. Trench (2012) found various motivations for science bloggers, including to enable conversations with the public, to find collaborators, to increase understanding of the science and to gain feedback. Schäfer (2012) found that science bloggers’

motivations ranged from giving them “an opportunity to discuss their finding with laypeople” to engaging people in “discussions of scientific issues that do not typically take place in the scientific literature” to enabling “the public to be included more extensively in science” (p. 350). However, despite the growing body of research into the activities of science bloggers and blogs, there has been very little research looking at how commenters (those who respond to blogposts and those who respond to the comments of others) engage with blogs, and whether the nature of their engagement reflects more deliberative discussions of science or reinforces top down communication approaches (Kouper, 2010; Schäfer, 2012; Brossard, 2013; Pearce et al., 2015). While there has been some research into the online comments of readers of science news in online newspapers (e.g. Collins & Nerlich, 2014; Koteyko et al., 2013), there is minimal research into the motivations of publics who comment on science blogs that are independent of mainstream news channels. Jarreau & Porter (2018) surveyed almost 3,000 readers of 40 science blogs, and presumably these readers also comment from time to time, but the survey focussed on motivations for these bloggers to read the blogs, not to comment on them. Interestingly, they found that, “The readers of science blogs as a whole are an elite, highly educated group of mostly scientists and future scientists who actively seek out science media content” (p. 159). But this thesis seeks to analyse the actual comments and dialogue on blogs to find out who engages in controversial science blogs by commenting. What are their apparent motivations for commenting? How do the blog commenters participate in a dialogue with each other and the people who posted the blogs?

This chapter attempts to explore these questions by analysing the comments on two prominent climate change blogs both produced by Australian science communicators. One is a proponent of the science showing evidence for human-induced

climate change, www.skepticalscience.com, and the other denies this science, www.joannenova.com.au. My investigation of two climate change blogs amongst thousands does not intend to be generalizable or representative of all climate change blogs. Rather, the study provides an in-depth examination of the nature of engagement occurring amongst publics in two highly polarised blogs, and the findings are contingent on that context. Regardless of the limitations of the research, my findings do say something important about how laypeople engage with climate change science through blogs. As I go on to elaborate, when taken with the findings from research into political blogs, observations from the following analysis do suggest both the opportunities and limitations that blogs may have as a tool in creating a dialogue about controversial science.

Some researchers see the ability of science blogs to engage publics directly as being an expression of the move over the past three decades towards more participatory science communication (Colson, 2011; Pearce et al., 2015). Kouper (2010) also highlights the potential of science blogs as spaces for public discourse but concludes that they can also be “used to reinforce the traditional top-down model of science communication” (p. 1). Similar findings about the limitations of social media, including blogs, and their tendency to reinvent established communication methods and styles have been found by other scholars, including Kahan et al. (2012), Pearce et al. (2015), Ritson (2016) and Trench (2012).

This chapter examines the comments to blogs on climate change science to see if there is a more deliberative engagement of laypeople in climate science through discussion on these blogs. Are people having a genuine dialogue about climate science? Are they deliberating about the science and its policy implications? My analysis of conversations between commenters engaging with polarised climate blogs seeks to

better understand how the predicted characteristics of science communication models, especially the dialogue model, translate into practice, and what this says about both the practice and the theorised models.

4.3 Study questions

The problem this chapter specifically addresses is: how do conversational responses by publics to climate change blogs reflect the theorised models of science communication?

Three subsidiary research questions explore this issue in depth with the two climate change blogs.

- (1) What objectives identified by various scholars in the theorised science communication models (see Chapter 2, Table 2) appear to be present in the comments to these blogs? (For example, do commenters appear to be wanting to disseminate information or deliberate on an issue?)
- (2) How are commenters engaging with each other through their conversations, and what does this tell us about the likely model of science communication being applied?
- (3) What is the quality of engagement between the commenters conversing, and how does this reflect the theorised models?

4.4 The study focus

4.4.1 Choice of blogs

The data analysed for this study were three sets of comments from three blog posts on each of the two blogs about the same three extreme climate/weather events—

<https://skepticalscience.com/> (SS) and <http://joannenova.com.au/> (JN). These two climate change blogs were chosen because they both:

- are well-established - SS began posting in 2007 and JN in 2008;
- have global reach - SS provides blogs in 20 different languages, and Sharman (2014) identified JN's blog as one of the three most central or influential sceptical blogs about climate change worldwide after comparing 171 blogs using social network analysis;
- are written by science communicators – SS was set up and is maintained by John Cook, a research assistant at the Center for Climate Change Communication at George Mason University while Joanne Nova is a pseudonym for Joanne Codling who has science communication qualifications and describes herself as “a self-employed science writer, graphic designer and illustrator, speaker and blogger”; and
- aim to use scientific information to support their claims and engage publics with climate science.

Unfortunately, I was unable to find any details of readership numbers for either blog, although JN says, “About 60,000 people join in each month” (2017). Both blogs seek to engage laypeople with science, and as such, offer a platform to compare the people interacting with these blogs and the nature of that interaction. Both blogs operate through the voluntary labour of the bloggers and by accepting donations. JN's blog seeks to refute the mainstream climate science views, where she believes (2017) “science is being exploited for financial gain, status and power”. The goal of SS (2017) “is to explain what peer reviewed science has to say about global warming”. It discusses the common flaws of sceptic arguments, in particular their tendency to focus “on narrow pieces of the puzzle while neglecting the broader picture” (2017). An article written by John Cook on research he and others carried out into climate consensus

(2014, p. 2) says the purpose of the blog is to “refute climate misinformation with peer-reviewed science”. JN’s ‘About’ page describes the political and economic issues associated with climate change, SS claims that the cause of global warming is a scientific question only, and that “SS removes the politics from the debate by concentrating solely on the science” (2017).

SS has a tighter moderator’s policy than JN with regard to making comments. It (https://www.skepticalscience.com/comments_policy.shtml, retrieved 18 May 2018) clearly states that all comments must be on topic, that there is to be no politics and that there is a “zero tolerance approach to trolling and sloganeering”. There is also to be “no accusations of deception...you may criticise methods but not their motives”. Personal attacks or name-calling are forbidden. JN’s ‘Rules & Legal’ section, has a much freer policy (<http://joannenova.com.au/rules-legal/>, retrieved 18 May 2018), and says they welcome constructive comments and questions and that the site relies on commenters “to use logic and reason”. The site also says, “If you are good-natured, funny or entertaining as well, you’ll get away with breaking all the rules above”. Comments are most likely to be deleted if they are “unnecessarily repetitive, rude, lazy or mindless, about administration/moderation, or too boring”. The different moderation policies of both blogs create an interesting point of contrast, which this study takes into account.

4.4.2 Choice of blogposts and comments

I looked at three sets of blog comments (Table 8) made on three blogposts on each blog about the contentious issue of how climate/weather extremes link to climate change. The first of these was Typhoon Haiyan, which affected the Philippines in November 2013. The second was the heatwave that struck Australia in January 2014, and the last was the floods that affected the UK in February 2014. These three posts were made around the same time period on both blogs and were chosen due to the likely higher

activity of commenters during such times of intense media and public scrutiny of natural disasters and their likely connection to climate change.

Table 8. Blog comments investigated from Skeptical Science and Joanne Nova’s blogs

Climate / weather event	Skeptical Science blog and number of comments	Joanne Nova blog and number of comments
Typhoon Haiyan affects the Philippines, November 2013	71 comments across 2 blog-posts; Nov 16, 2013: https://www.skepticalscience.com/super-typhoon-haiyan-michael-mann.html Nov 20, 2013: https://www.skepticalscience.com/will-super-typhoon-haiyan-become-norm.html	141 comments; Nov 26, 2013: http://joannenova.com.au/2013/11/sleep-walking-to-extinction-or-maybe-communism/
Heatwave affects Australia, January 2014	56 comments; Jan 17, 2014: https://www.skepticalscience.com/australias-hottest-year-humans-caused-it.html	260 comments; Jan 16, 2014: http://joannenova.com.au/2014/01/forgot-ten-historic-hot-temperatures-recorded-with-detail-and-care-in-adelaide/
Floods affect United Kingdom, February 2014	97 comments; Feb 15, 2014: https://www.skepticalscience.com/2014-SkS-Weekly-News-Roundup_7.html	252 comments; Feb 14, 2014: http://joannenova.com.au/2014/02/uk-met-office-predicts-15-chance-of-heavy-rain-britain-gets-biblical-floods/

4.5 Methods

To find out more about **who was commenting** on the blogposts shown in Table 8, I coded all the blog comments according to the:

- a. assumed gender of the commentator – if apparently male or female according to their name, or if there was a pseudonym used (for those whose names were not clearly male or female, e.g. “Leigh”, they were included as a pseudonym); and
- b. individuals making comments to determine whether some commenters spoke more than others within and across blogs

I also looked at whether blog commenters used technical or non-technical language.

To try to determine the **apparent motivations** for commenters engaging with the blogs, I used thematic content analysis (Cho & Lee, 2014) to code all the comments according to the likely science communication objective the commenter was trying to

achieve. The codes were derived using a deductive approach to analyse comments against the most common science communication objectives identified in the literature about science communication models, as shown in Table 9. These objectives go from deficit, to dialogue, to participatory model objectives.

An independent researcher used a code guide to analyse a random sample of 25 comments from each of the six blogposts (17% of all comments) to compare with my coding (Lombard et al., 2004 suggests a sample of 10% is sufficient to test intercoder reliability). There was good overall agreement with my coding, but in discussions with the independent researcher, we agreed that it was difficult to determine the main objectives related to some comments. For example, it was difficult to differentiate whether a commentator was disseminating information or seeking to educate others. We agreed, that my coding results focus on obvious trends, and examples of those trends rather than any quantification of the coding.

Table 9. Science communication model objectives analysed in comments

Objective	Literature
Deficit model	
To disseminate	Bucchi, 2004; Callon, 1999; Joly & Kaufmann, 2008; Irwin, 2008; Trench, 2008
To promote	Trench & Junker, 2001; Kurath & Gisler, 2009; Brossard & Lewenstein, 2010; Scheufele, 2014
To interest or inspire	Miller, 2001; Bucchi, 2008; Scheufele, 2014
To educate	Callon, 1999; Trench & Junker, 2001; Stocklmayer, 2013
To influence (attitudes/behaviours)	Durant, 1999; Höppner, 2009; Stocklmayer, 2013
Dialogue model	
To access information / expertise	Trench & Junker, 2001; Bucchi, 2008; Irwin, 2008; Palmer & Schibeci, 2012
To discuss	Durant, 1999; Bucchi 2008; Kurath & Gisler, 2009; Irwin, 2008
To debate	Durant, 1999; Bucchi 2008; Kurath & Gisler, 2009; Irwin, 2008
To consult	Callon, 1999; Durant, 1999; Miller, 2001; Trench & Junker, 2001; Rowe & Frewer, 2005; Bucchi, 2008; Pouliot, 2009; Höppner, 2009; Brossard and Lewenstein, 2010; Stocklmayer, 2013; Scheufele, 2014
Participatory model	
To deliberate about an issue where science has a role	Callon, 1999; Durant, 1999; Rowe and Frewer, 2005; Stocklmayer, 2013
To make a decision using scientific input	Trench and Junker, 2001; Brossard and Lewenstein, 2010; Höppner, 2009; Palmer and Schibeci, 2012
To co-create new knowledge or products	Callon 1999; Bucchi, 2008; Pouliot, 2009; Stocklmayer, 2013

To find **how commenters were engaging** conversationally with the blogs I firstly analysed blog comments to identify statements that indicated a particular mode of participation that commenters had with each other and the blog. I used the four overall modes of participation identified by Kouper (2010) to code the data to look at whether blog comments were:

1. contributing to the topic – e.g. reporting from an external report or source; making an argument that adds to the topic, explaining more about the topic or asking questions of clarification;
2. deviating from the topic – e.g. digressing, insulting, self-promotion;
3. expressing attitudes or emotions – e.g. approval, disapproval, regret, personal experiences, anger; and
4. attempting to influence others' actions through advice, recommendations, requests and proposals.

Those commenters who are 'contributing' are more likely to be engaged in response to a dialogue with others, although they may be transmitting information, new ideas and data more typical of the predicted objectives of the deficit model. Those who are 'deviating', 'expressing attitudes' or 'attempting to influence others' are likely to be also reflecting objectives more typical of those predicted for the deficit model. I analysed all comments, and each comment could have more than one mode of participation. An independent researcher coded a random sample of 25 comments for each blogpost and found a 90 per cent agreement with the original coding.

The study also investigated the quality of engagement commenters were having with each other through their discourse. Discourse analysis emphasises the contextual and rhetorical nature of the language used as people interact, and hence gives insights

into how people engage with each other. Was the dialogue encouraging further discussion? Was the discussion open to new, different or contradictory ideas? How were newcomers to the discussion treated? This study's analysis builds on the concept of discourses being dialogically expansive or contractive (White, 2003). Dialogically expansive conversations are where commenters **entertain** other positions compared to what is being referenced (e.g. If we are seeing a rise in more extreme events, *perhaps...*) or where they **attribute** a viewpoint to one external voice amongst many (e.g. Dr X *claims...*). This type of engagement is more likely to be happening when the engagement is more two-way than one-way, and where participants are actively listening and responding to each other. Dialogically contractive discourses are much more about people engaging in one-way communication, from their own soapboxes. Such discourses tend to close down conversations through statements that **proclaim** certainty for a point of view through pronouncements (e.g. *I would contend* that climate change is...), concurrence (e.g. *Of course*, there is no evidence...), or endorsement (e.g. Professor Y *shows* that...). Such dialogically contractive statements display the commenters "personal investment in the viewpoint being advanced and accordingly increases the interpersonal cost for any who would advance some dialogic alternative" (Kouper, 2010, p. 271). Other dialogically contractive statements **disclaim** by denying (e.g. The new policy will *not* solve the problem) or countering (e.g. We *already* have the data available about...). Another form of dialogic contraction is **justifying** a specific viewpoint of position to win over or influence others (e.g. This interpretation of data is based on subjective analysis and *therefore* should be absolutely rejected...). An independent researcher conducted an intercoder reliability check by analysing a random selection of 17% of the comments using a code guide. There was very good overall agreement (90%) with my coding and any differences were discussed and resolved.

4.6 Analysis

4.6.1 *The commenters*

Across all three blog comments, SS had 55 different commenters making a total of 224 comments. JN had 179 commenters making 653 total comments. Of these commenters, SS had three commenters, who commented across all three blogs, making 29 per cent of all comments. Likewise, JN had 20 commenters, also commenting on each of the three blogs, making 30 per cent of the comments. For both SS and JN's blogs, another third of comments were made by, respectively, 11 and 24 commenters, who commented on two of the three blogs. This shows that most of the comments (about 60 per cent) on both blogs are being made by a core group of active commenters who make up about one quarter of the total number of commenters for each blog. Others drop into the conversation on an only occasional basis. This was a similar finding to an analysis by Collins and Nerlich (2014) of commenters to online *Guardian* articles on climate change.

For both blogs, commenters with male names dominated compared to the few who had female names (see Table 10). It is possible that females may be disguising their participation through the use of male names (Armstrong & McAdams, 2009), and as such I can only comment on the dominance of assumed male names for commenters. SS had more pseudonyms compared to those clearly identified as male and JN had a majority of commenters who had assumed male names. In their survey of science blog readers, Jarreau and Porter (2018) also found that the majority (55%) reported being male, which compared to 37% identifying as female (the rest did not answer or identify as one of these sexes).

Table 10. The apparent gender of the blog commenters as a % of all bloggers

Gender	Skeptical Science %	Joanne Nova %
Male	44	61
Female	2	4
Pseudonym	54	35

More of the commenters from SS used formal, technical language compared to JN commenters who were more likely to engage in short quotes using colloquial language. In fact, a significant proportion of SS's commenters' contributions were so technical that even a reasonably well-educated person working in the climate change arena might have difficulty understanding the content. It is possible that many of those participating in the blog as commenters are scientists or have a technical background, which may not be surprising given the aim of the blog is to convey the science of climate change. Jarreau and Porter (2018) likewise found in their survey that the vast majority of readers of scientific blogs were either pursuing or engaged in a science-related career. The scientific and technical nature of many of the comments is illustrated in an extract from a comment made by 'Tom Curtis', participating in the SS's blog on the UK floods. This level of detail is not unusual for SS commenters.

Just addressing the evidence before the IPCC, we have OAGCCM models with equilibrium climate sensitivities ranging from 2 to 4.6 C/x2CO2... Empirically, from the instrumental record, we have values from 0.8 (Lindzen and Choi) to 5 C/x2CO2, with 8 out of 20 being below 2 C/x2CO2, and 5 being 3 C/x2CO2 or above. Empirically, from climatological constraints we have three results, all lying between 3 and 4 C/x2CO2.

4.6.2 Motivation to comment on blogs

Coding of the comments according to the likely objectives of the commenters to engage in the blog indicated it was very hard to determine the exact objective of a commentator other than to merely discuss things with each other or to debate outsiders. About half of the comments for both SS and JN blog-posts involved commenters conversing with

each other in a discussion about a topic that interested them.

Around one third of the comments made to Sceptical Science appeared to be motivated by a desire to ‘disseminate’ information or to ‘educate’ people further about the science. JN commenters appear to be much less likely to be motivated to ‘disseminate’ to or ‘educate’ people. However, unlike SS, JN commenters often seemed to make comments designed to interest or entertain other commenters in what they were saying. For example, regular JN blogger, Rereke Whakaaro, comments in the Haiyan blog discussions, “I was once told a joke by a Russian, ‘Why do the KGB go around in threes? Well, one can read, and one can write, and the other is there to watch the intellectuals’” (sic).

For both blog sites, the conversations appear to be largely between like-minded people who generally agree with the stance taken by the others commenting on the blog. When someone who disagrees with this stance enters the conversation they are usually fiercely debated (as in SS blogs) or attacked (as in JN blogs) by all the other commenters. For example, climate change sceptic Russ R. makes 23 comments on SS’s UK floods blog-post in a discussion where all the other commenters seek to rebut what he says. JN’s commenters likewise attack those who dare to enter their conversation with a different view. Blackadderthe4th enters the Haiyan (makes 6 comments) and Australian heatwave blog discussions (makes 2 comments); Chester enters the UK floods discussions (makes 6 comments), JenJ (makes 1 comment) and Philip Shehan (makes 31 comments) enter the Australian heatwave discussions. Dissenting commenters mostly have a short-lived engagement with the rest of the commenters, which is likely due to the personal attacks they receive. For example, moderator Jo Nova enters the conversation to attack blackadderthe4th in the Haiyan discussions:

BA We are bored of your mental inability to accept the plain basic truth that we have told you 50 times. Hansen 1984, Bony 2006, IPCC 2007, over and over they all agree that CO2 causes 1 degree of warming per doubling, and all the warming above that comes from **assumptions about feedbacks** of which there is no evidence. If you want to keep posting here, you need to stop posting primary school arguments which only show you are in denial.

However, in each blog there is one example of more sophisticated engagement between commenters where they appear to want to deliberate an issue. For example, Bruiser makes 10 comments on SS's Australian Heatwave blog-post and some of Bruiser's questioning causes Tom Curtis to rethink his analysis:

Bruiser will not be convinced, and nor should he be convinced, by this that he is wrong in attributing most of the increased temperature to the high solar exposure. The error margins are too large. Neither should he be convinced from this that he is correct, for the same reason. I have tried to be conservative in my calculation, and to the extent that I have succeeded, that means it is more likely that the errors will have favoured his case rather than undermined it, and therefore, that an error free calculation would show his case to be wanting. Therefore, I do not believe we can use direct calculation of the transient forcing to further the discussion (contrary to what I attempted). This does not mean Bruiser should not be persuaded by the first part of my discussion.

A pro climate-change science commenter entering JN's Australian heatwave discussion, Philip Shehan, has an ongoing dialogue with another commentator, Sheri B, about scientific publication and media publicity and she ends that conversation by appreciating his contributions:

I will read through the papers. Fascinating work. You kind of answered my first question. It seems some papers lay aside and show up much later! Still, there's a lot of good research out there that is never published, I would think.

Throughout their conversation, Philip and Sheri appear to deliberate about the role and

use of scientific publications. However, other commenters on JN's blog are very rude to Philip and he stops contributing after Vic A Gallus posts, "What a t#d! It should have been obvious in my comments that I have published and reviewed papers. As I have a dig at an editor, it was best not to be specific, you idiot". This is an example of the incivility that can be created during such blog discussions (Collins & Nerlich, 2014).

In Jarreau and Porter's (2018) survey of almost 3,000 readers of 40 science blogs, they found the motivations for readers to come to the science blogs were:

"...seek out information they cannot find other places... but also to be entertained, to interact with a community of like-minded users, and to seek out the specific perspectives and expertise offered by their "favorite" science bloggers. (p. 160-161)

Certainly, in the blogs I examined, people appear to be mostly engaging with the blogs to interact with like-minded people, and to some extent, especially for JN commenters, be entertained. There appears to be less evidence that they are coming to seek out information or the perspectives of their favourite bloggers, rather they appear to be providing information or educating others.

4.6.3 Nature of engagement

Commenters engaged in the blogs mostly by contributing information or knowledge ('contribute') or, especially for JN commenters, by expressing some sort of attitude or emotion ('emote'), as shown in Table 11. There was also a level of deviation from the topic, especially by JN's commenters. The increased likelihood of JN commenters deviating from topic or expressing attitudes likely reflects their freer moderation policy. Only a few commenters sought to influence people, and this is probably because most of their conversations were with like-minded people.

Table 11. Modes of participation in blogs by commenters as a % of total comments for each blog-post (NB. each comment may have more than one mode of participation)

Blog	Haiyan		Australian heatwave		UK Floods	
	SS	JN	SS	JN	SS	JN
Contribute	61	24	93	52	74	42
Deviate	18	42	0	15	4	24
Emote (show attitudes)	25	70	13	51	59	53
Influence	21	7	0	0	3	0

JN's commenters often deviate to topics that reflect their political leanings. For example, there's a whole thread about Korea and socialism in the Cyclone Haiyan blog. However, not all deviations from the blog topic are political; some are conversations that spark people's interest or sense of humour. For example, in response to the JN's blog-post about the UK floods, commenters deviated at length to discuss the names of rivers and which river in the world had the longest name. Such deviations may indicate underlying attitudes to climate science, but this was not something I explored in this research.

The attitudes or emotions expressed by JN commenters are generally directed at:

- (a) an organisation (e.g. Australian Bureau of Meteorology / UK Meteorology Office – “The Met. O is so fixated on the global heating narrative, as we must call it, that they don't even bother to check their own records when coming up with the next epicycle.”);
- (b) an individual (e.g. Julia Slingo from the UK Meteorology Office – “Dame Julia Slingo? The name says it all. HAHAAHAHA!”);
- (c) ‘Warmists’ or ‘Alarmists’ who are perceived to be acting through a desire for personal gain (e.g. “...the alarmists warmists in their outright ignorance and narrow mindlessness haven't got a bloody clue about the utter severity of frequent past historical weather events”);
- (d) experts (e.g. “...the engineer's working definition of an ‘expert’, i.e. ‘x’ is an unknown quantity and a ‘spurt’ is a drip under pressure”);

- (e) people who come into the debate who disagree with the stance of the commenters (e.g. blackadderthe4th who enters the Cyclone Haiyan discussion, Chester who enters the UK floods discussion and Philip Shehan who enters the Australian heat wave discussion); and
- (f) political policies, agendas or ideologies, especially those perceived to be socialist, communist or “green” (e.g. “Your examples go to the heart of green logic. Logic that is fatally flawed at its core. That logic being high population and development = lower standards of living.”)

SS commenters are more likely than JN commenters to contribute information, links to further information and new ideas about some of the data. In line with the blog’s moderation policy, they are less likely to show their attitudes or emotions during a discussion. This is likely because regular commenters know the ‘rules of the game’ along with the active moderation of this site, (e.g. the moderator often asks commenters to “lose the snark”). However, when someone with an opposing view (Russ R.) entered the discussion about the UK floods, the attitudes and emotions of the SS commenters emerged. For example, SS’s most prolific commentator, Tom Curtis, who generally tries to focus on the science, loses some of his usual patience when Russ R. accuses him of cherry picking:

Russ R @82, I find it seriously offensive that mister ‘only studies which find low climate sensitivity are valid’ should accuse me of cherry picking...If you are going to accuse me of cherry picking for pointing to instances that falsify your claims, this discussion is over. If you want it to continue, I expect an apology. If that is not forthcoming, I have done more than enough to show that on the science of climate change you are ignorant, and in fact dismiss any data you find inconvenient from consideration.

The discourse in both blogs was dialogically contractive in nature. More than half of all comments made were proclamations of knowledge or information, indicating only one-way engagement with their fellow commenters. SS commenters made almost as many comments that were disclaiming in nature, while about a quarter of JN's comments were disclaiming. A smaller number of comments for both blogs were about justifying a specific position, which is probably not surprising given the conversations appeared to be mostly between like-minded people. The commenters on both blogs were disinterested in entertaining alternative opinions to their own beliefs. Some commenters, especially for SS, would attribute their comments to other sources of expertise. Even when commenters were debating a particular point, the nature of the discourse was largely contractive meaning there was no true dialogue where commenters were actually listening to each other and then responding. This is demonstrated in Extract 1 from JN's heatwave blog, which shows part of a discussion between an outsider (blackadderthe4th) and other JN commenters. Blackadderthe4th (BA) starts by **proclaiming** some facts through endorsing a BBC report. Heywood then responds to **justify** their viewpoint by implying that BA "falls for" the propaganda of the BBC. Heywood then goes on to **disclaim** BA's posting by pointing out that the whole country is not affected by the heatwave before **proclaiming** the issue as being about global warming. BA responds by **endorsing** a new source, Dr Andrew Dessler. The moderator, Joanne Nova, then enters the conversation to **disagree** with and **counter** BA's comment. This sequence of comments is typical of most of the conversations in both blogs when someone with a different view to most of the commenters enters the discussion.

Extract 1.

blackadderthe4th: As it is being reported in the UK! 'Australia heatwave prompts fire alerts' South-east Australia has been hit with extreme hot weather, with

temperatures of over 40C (104F) in some areas, and several bushfire warnings in place... Last year was recently declared Australia's hottest on record, further raising questions about the impact of climate change, our correspondent adds...

<http://www.bbc.co.uk/news/world-asia-257238>

Heywood: Ahhh the good old BBC Climate Propaganda Unit, and BlackIdiotLevel4 falls for it. The BBC stooge falls for the same rhetoric. 'Last year was recently declared Australia's hottest on record'. Only in three states actually, not the whole country, but we mustn't let the truth get in the way of a good dose of scaremongering shall we. Luckily, the issue isn't Western Australian warming, or even Australian warming. It is GLOBAL warming...

blackadderthe4th, 'Ahhh the good old BBC', but not only the BBC! Dr. Andrew Dessler testimony: 'I am Andrew Dessler, I am a professor of atmospheric science...first the climate is warming...overall increase...the most recent warming is most likely due to the emissions of co2 and other GHG by human activity ...

Jo [moderator comment]: BA I always admire how Dessler can frame a line that makes it look like the models "worked" in two specific small instances, while ignoring the failure in global trends, upper troposphere, the Antarctic, rainfall patterns, and cloud cover.

4.7 Discussion

4.7.1 Blogs on controversial science like climate change create own publics

Conversations on the two climate change blogs that I examined appear to be dominated by a small number of people with assumed male names or pseudonyms who reaffirm their social identities by conversing within their own communities (Myers, 2009) rather than allowing outsiders to enter their conversations. These two climate change blogs represent two polarised communities at different ends of scientific thinking about climate change. The dominant discourse in each blog is between like-minded people who create in-group and out-group social identities, which are largely based on how they perceive climate change science (Jaspal et al., 2012; Riesch & Mendel, 2013). In this way, such blogs appear to create and maintain their own publics, through the process of engaging regularly in the blog people become part of a new public, which is

separate from the general public (Marres, 2005; Mohr et al., 2013).

These findings reflect research into political blogs (e.g. Hewitt, 2006; Sunstein, 2007), which found that bloggers on those sites “focus on selectively spinning the issues at hand for their largely partisan audiences” (Meraz, 2011, p. 110). Soon and Kluver (2014, p. 501) review the literature on political blogging and conclude that: “bloggers connect with others whom they perceive share similar ideologies”. This results in separate and polarised blog sites with differing publics (e.g., Hewitt, 2006; Sunstein, 2007). A similar result was found in research looking at Twitter conversations about climate change following the report from the 2013 Intergovernmental Panel on Climate Change’s Working Group (Pearce et al., 2014, p. 9): “people are more likely to make conversational connections with those who broadly share their views on climate change”. A behavioural study of online users (Jang, 2014) found that users of global warming information were likely to seek information that was congruent with their existing views, reaffirming the formation of ideological-based publics. While the creation of like-minded publics is not a bad thing in itself, the relatively homogenous and separate groups that result are likely to inhibit online dialogue about the science (Meraz, 2011).

4.7.2 Commenters use blogs as a ‘soapbox’

Commenters on both blogs appear to be using these blogs as platforms to discuss their own interests, which are also the interests of their like-minded colleagues within their in-group. This finding is indicated by the high percentage of commenters participating by contributing to the discussions for both blogs (see Table 11), and by their responses to people who enter the discussions with a different view. As such, it is likely that commenters may initially participate as laypeople, but such people are likely to be attracted in the first place by the ideology of the other bloggers. Once they become

regulars within the in-group, they are likely to cease being a ‘layperson’, as they share in the expertise of the wider group and establish their own blog profile. The technical nature of many of SS’s blog-comments also likely acts as a barrier to laypeople engaging very much with discussions on that blog.

The dialogically contractive nature of the conversations between commenters, especially when someone outside the in-group makes a comment, serves to reinforce the deficit style of engagement between commenters. SS’s commenters seem largely to be driven to engage in the blog to share or educate about new climate science knowledge or to debate anyone who dares to question the agreed knowledge of the in-group of commenters. JN’s commenters are most interested in conversing with and amusing each other and sometimes sharing links and ideas. They will personally attack anyone who enters the conversation with a different view. In this way, they are engaging in a dialogue, but one that fails to deliberate on the science. The conversations on both blogs are unlikely to be productive and are more reminiscent of people “shouting their opinions from the rooftops” (Trench, 2012). Commenters for both blogs do not tend to engage deliberatively with those of opposing views. They are unwilling to move the conversation into a dialogue that explores alternatives or new ways of thinking about the climate science knowledge. It appears that the “cultural politics of climate change” noted by Boykoff (2011, p. 3) where each actor in the debate seeks to advance their own rhetorical and ideological objectives is alive and well in the two climate change blogs I analysed. When an outsider joins the conversation, the debate gets heated with a tendency for commenters to focus on who is making the argument and how rather than the substance of the issue, something which Trench’s (2012) review of scientists’ blogs also noted. Wang’s (2010) research into political blogs similarly found that commenters

involved in campaign blogging focused on attacking opponents rather than developing political policies around issues.

4.7.3 Commenters use deficit-style communication

The style and nature of interaction between commenters was remarkably similar between the two blogs, and many of the differences between the discussions can largely be put down to their different moderation rules. Skeptical Science's deliberate exclusion of political, social and economic issues from the discussion of climate change science reduced discussions about attitudes, policies and people's role in the science. This serves to reinforce a deficit rather than a deliberative form of engagement, as predicted through dialogue and participatory models. However, the strong partisan flavour of JN's blog and her free moderation policy means the conversations on her blog often degenerate into attacking people and institutions rather than being reasoned discussions about the science.

The analysis of the comments on these two polarised blogs indicates there is a narrowing of scientific debate to one dominated by a few major commenters who have little patience with others who disagree with their point of view; they are each preaching to the converted. This means that, at least for these two blogs, there is little deliberation of climate science and its role in society. Rather, the dialogue that occurs in these blogs offers spaces for like-minded people to discuss controversial science topics with each other using deficit-style communication. While that interaction, in itself, may prove to be a useful engagement that furthers that group's thinking and deliberation about the science, it is not achieving the promise that blogs gave of more inclusive and deliberative engagement with science. There is also the danger that such blogs lead to "a fragmentation of online debates into small, not interconnected sub-publics" (O'Neill & Boykoff, 2010, p. 239). Further research on the comments of other controversial

science blogs is needed to further explore my findings and look for other methods for encouraging more deliberate dialogic engagement of laypeople in publicly contested science.

4.7.4 Limitations and further research

The major limitation of this study is its focus on just two climate change blogs among many. There is also limited information on the publics commenting on these blogs with regard to their backgrounds and explicit motivations for being engaged. However, this study does provide some interesting reflections on the potential of blogs to create more deliberative dialogue with publics about controversial issues. By analysing the comments of those posting responses to science blogs, new and different perspectives on the nature of engagement have emerged. Such research into blog comments has been done extensively for political blogs, but not for science blogs. It would be useful to expand this research, for example by using tools other than textual analysis to explore the demographics and motivations of those engaging in such blogs.

Future research could look at the potential of blogs for engaging publics in other controversial science topics or in non-controversial science. When reviewing science blogs, Trench (2012) noted:

the case of climate science is in many respects special: Political and ideological factors are prominently in play, including through the involvement in the public debates of ‘amateurs’ who may have technical competence to follow the arguments but whose main motivation for becoming involved is to fight a cause.

If this is the case, then research may find that blogs on different controversial issues may be more likely to attract more deliberative dialogue in their blog conversations.

4.8 Concluding remarks

The analysis of the comments on two antithetical climate change blogs indicates a narrowing of scientific debate to one dominated by a few major commenters who have little patience with others who disagree with their point of view. This means that, at least for these two blogs, there is little deliberation of climate science and its role in society. Rather, the dialogue that occurs in these blogs offers spaces for like-minded people to share information on controversial science topics through deficit-style motivations: to be heard, to disagree, and to provide what they consider to be the best information or argument. Furthermore, the nature of commenters' dialogue in commenting on the blogposts took on deficit-style characteristics. This reinforces the findings of the last chapter, which found that it is hard to separate out activities as having just one set of characteristics typical of only one of the theorised science communication models.

The results of this chapter also indicate that we can't assume deliberative dialogue is happening when apparent dialogue tools, such as those provided by social media, are chosen. With a controversial topic like climate change, it is highly likely that any blogs will lead to increased polarisation of the issues through deficit-style conversations that serve to create and reinforce the views of insular publics. Such insular publics reflect the values and beliefs of the person who initiates and maintains the blog.

The next chapter uses a long-term participatory science communication program, the Climate Champion Program, to further explore how theorised models of science communication are translated into practice. In particular, I explore the motivations of the participants of this program, and the characteristics of their engagement with each other. This next chapter will explore how an intentionally

participatory science communication program uses upstream engagement of its participants to critically reflect on science and its products, as well attempt to solve the problem of managing climate risk. The results of this analysis should tell us even more about how science communication models might be shaped and further investigated by scholars, and what the implications are for practice.

5. Comparing science communication models with a long-term participatory case study—The Climate Champion Program

5.1 Introduction

The last two decades have seen calls by scholars for science communication to become participatory in nature, and to move away from linear (deficit and dialogue) engagement of publics. Theorised participatory science communication happens when scientists and publics directly interact in a process that scholars argue leads to a greater democratisation of science (Brossard & Lewenstein, 2010; Bubela et al., 2009; Joly & Kaufmann, 2008). Scientists do not necessarily drive the participative process and publics may initiate and direct the engagement. This contrasts with the theorised deficit (one-way communication from scientists to public) and dialogue (two-way communication between scientists and publics) models of science communication, usually initiated by scientists (Rowe & Frewer, 2005; Bucchi, 2008). Irwin (2008 p. 169) calls for a ‘third order’ style of thinking that puts science-public relations in the wider context, to “open up fresh inter-connections between public, scientific, institutional, political and ethical visions of change in all their heterogeneity, conditionality and disagreement”. Participatory science communication is theorised to possess an openness between participants and a deliberative democratic potential that linear models of science communication failed to deliver in practice. Achieving such a democratic potential relies on scientific governance to change its notions of power and control (Irwin, 2006; Stirling, 2008).

In the case of publicly controversial science, some scholars (Callon, 1999; Jackson et al., 2005) assert that a participatory model of science communication is more likely to create positive change when compared to linear communication, regardless of whether it is one-way or two-way. When the science is controversial, scholars predict

that participants involved in a participatory science communication program can take an open role in critically reviewing research and its products, solving problems, or supporting behaviour and policy changes (Few et al., 2007; Höppner, 2009; Marquart-Pyatt et al., 2011).

Climate change is a publicly controversial scientific issue debated in many countries, including Australia, the USA and the UK. In these countries the science has become politicised resulting in a polarisation of views (Brin, 2010). The success of climate change policies and international treaties to reduce emissions will likely depend on broad public support and participation (Swain, 2012). Likewise, if publics are to adopt new behaviours to mitigate or adapt to climate change, they are unlikely to be convinced by facts alone so new more participatory forms of engagement are needed (Roberts, 2013). Unfortunately, traditional deficit-style means of communicating with the public through mass media has only served to polarise views further, and quality traditional news coverage only reaches a small audience of already engaged citizens (Swain, 2012).

In response to calls for more deliberative and open engagement of publics in controversial scientific issues, such as climate change, a number of participatory science communication methods have emerged including consensus conferences and citizen juries. Bucchi and Neresini (2008) describe the characteristics and duration of some of these methods including referenda, hearings and inquiries, and negotiated rule making. Most of the methods occur over a short period of time, except for negotiated rule making whereby a working committee of stakeholders may last days to month as they seek consensus on specific questions. However, while there is significant research on short-term participatory science communication practices (e.g. Kurath & Gisler, 2009),

there has been little research on how the theorised model of participatory science communication has been put into practice in longer-term projects.

This chapter empirically examines a participatory science communication case study in Australia whereby scientists and farmers participated jointly in a Climate Champion Program that ran over seven years between 2009 and 2016. The Climate Champion Program purposively created opportunities for scientists and farmers to directly and openly participate with each other in understanding and managing climate risk. The Program was largely substantive in its original motivation in that its objectives and processes were negotiated amongst its participants (Mohr & Raman, 2012; Stirling, 2008). However, as discussed, the science communicators coordinating the program, the funders of the program and the participants also demonstrated normative and instrumental motivations. In the first instance, and from instrumental motivations, the Climate Champion Program arose and was funded as those involved in funding agricultural research perceived that the traditional means of extending that research had failed (Sheng, Mullen & Zhao, 2010). This Program appeared to offer a new opportunity for relevant climate and agronomic scientists to share their research with a core group of farmers, who would ideally share that research with other farmers. I investigate this program against the predicted aspects of the theorised science communication models put forward by scholars, as summarised in Chapter 2, Table 2.

5.1.1 Agricultural extension and participatory science communication

Within the agricultural community, there has long been a history of ‘extension’ whereby scientists, extension officers and farmers interact and engage with each other. In many ways, the evolution of agricultural extension has paralleled the development of science communication models. The Australasia-Pacific Extension Network (APEN) defines extension as “working with people in a community to facilitate change in an

environment that has social, economic and technical complexity” (<http://www.apen.org.au/what-is-extension>). It can be achieved by “helping people gain the knowledge and confidence so they want to change and providing support to ensure it is implemented effectively”. APEN postulates that each step in the extension process is active and participatory. Extension is seen to be an education process (capacity-building), which takes genuine engagement. The responsibility of decision-making is a shared one with the aim of achieving greater personal and group ownership of decisions (empowerment). This modern interpretation of extension compares with earlier ones, which were far more ‘top-down’ with the one-way transfer of knowledge from scientists to extension officers to farmers, reminiscent of the deficit model of science communication. The more modern take on extension has changed and evolved from “old ‘training and visit’ models” to “playing the role of broker between different actors” (Sabbagh, 2013).

However, the level of Australian public investment in extension has declined over the years, along with decreasing investment in agricultural research and development (Sheng, Mullen & Zhao, 2010). The traditional role of Australian state governments in providing free extension services to farmers through extension officers has virtually disappeared. Instead, rural research and development corporations (RDCs), funded jointly by industry levies and public funds, along with private consultants have become more prominent in the extension space. Most RDCs see extension as being essential to improving rural productivity and sustainability. However, they also acknowledge the myriad of complex communication and delivery channels for providing extension (Department of Agriculture Fisheries and Forestry, 2010, p. 36):

...while in each industry extension operates differently, extension is now a maze of different providers and access points, through private consultants, agribusiness and input suppliers, local grower [farmers who grow crops] groups, and public

information obtained through the internet, conferences, demonstrations, workshops and publications.

Interestingly, this quote indicates that more traditional means of extension using one-way communication from scientists to farmers through mechanisms like websites on the Internet, conferences, demonstrations and publications are still likely to be common means of engagement.

As mentioned in the introduction to this section, the Climate Champion Program largely arose because of the demise of the traditional extension services and the recognition by RDCs that such a program might help to transfer their research to farmers and increase adoption. The RDCs did not perceive of the program as a ‘participatory science communication’ program but saw it as a high-risk enterprise. I, with others, was able to persuade them of its potential benefits as outlined in the next section. This chapter examines the nature of the participatory ‘extension’ that resulted through the program.

5.2 The Climate Champion Program (CCP)

5.2.1 Rationale for CCP

Climate risk is arguably the largest challenge that Australian farmers face given that they operate on the driest inhabited continent with the world’s most variable climate, which is becoming even more variable with climate change (Cleugh et al., 2011).

Farmers are likely to be the group most directly affected by climate change in Australia (Fleming & Vanclay, 2009). Climate change is predicted to result in diverse, uncertain and possibly catastrophic consequences for Australian agriculture (McEvoy et al., 2010). Such predictions reduce even further farmers’ capacity to plan for and manage their seasons (Hochman & Carberry, 2011). It is therefore crucial that Australian farmers

have the latest tools for forecasting and managing the seasons and years ahead. Farmers need to make some tough decisions, and they need to make these based on the best available evidence if they are to continue to farm sustainably and profitably. Farmers need access to well communicated and relevant knowledge, something they used to get through government extension services, which has diminished sharply over the last two decades (as discussed previously).

The overarching goal of the CCP was to support leading farmers across Australia in communicating with their peers about climate science and the means for adapting to and managing climate risk. Climate change remains a controversial issue in Australia, and while Australian farmers have long accepted the reality of climate variability, their attitudes to climate change science have tended to be at the sceptical end. This was especially the case at the start of the Climate Champion Program (2009). For example, a survey of 255 farmers in Western Australia in late 2008 (Evans et al., 2011) found that only one third agreed that climate change was occurring, and just 19 per cent believed climate change was human induced. More recent surveys as reported in the media (e.g. Barlow, 2014; Chang, 2016) suggest greater acceptance by farmers of human-induced climate change.

The CCP was initiated in 2009 and sponsored through the national Managing Climate Variability (MCV) research and development program and Grains Research and Development Corporation (GRDC) communication strategies. MCV is funded through a consortium of RDCs, including the GRDC. The CCP was the major component of both strategies in terms of investment and time. The initiative was recommended in response to research that indicates that those involved in primary industries – farmers, foresters, fishers - learn best from their peers, and will adopt practice changes in response to what their peers are doing (Jacobi et al., 2011; Patel et

al., 2012). Research also indicates that the best capacity-building processes combine peer learning with access to trusted professionals (Child, 2010).

The focus of the research of the MCV program, and to some extent the GRDC-funded research, was to provide farmers with better seasonal forecasting tools to manage their climate risk. Seasonal forecasts use scientific models to predict the climate in the coming months. Seasonal climate forecasts have the potential to improve farm profitability, minimise land degradation, assist with drought preparedness and reduce vulnerability to future climate change (Hansen et al., 2006). However, the challenge of communicating seasonal forecasts is the probabilistic nature of such forecasts, which means they include a degree of uncertainty and can be complex to explain. A 2008 MCV analysis of farmers' needs from seasonal forecasts asked for feedback on some of the Australian Bureau of Meteorology's draft seasonal forecasting products. This study (Land and Water Australia, 2008, p. 25) found there was a need for MCV and the Bureau to "work with target users, in a participatory style of science communication" to help jointly develop clearer explanations of climate risk and the terms used to explain that risk. The CCP was also a response to that finding in that it was thought that a group of leading farmers would provide an accessible means of providing feedback to scientists about proposed research products and communication tools. In summary, there were all three forms of participatory motivations for the program: normative because it seemed like a good thing to get farmers and scientists talking and listening to each other; instrumental so that more farmers would adopt seasonal forecasting tools; and substantive in that better outcomes would be achieved by farmers and scientists working together to critically evaluate research directions as well as design and test communication approaches and tools.

My study focuses on the participation of climate champion farmers with scientists rather than their participation with other farmers. The CCP, through my science communication company Econnect Communication, supported participant farmers by developing their communication skills; assisting them with media and speaking engagements; organising workshops and field trips involving scientists; creating opportunities for them to interact with or question scientists; providing them with plain English scientific summaries; and profiling them through case studies on the MCV website. The Econnect project manager for CCP, Sarah Cole, said she spent time almost every day of the seven years of the Program responding to CCP farmers' requests for assistance, and putting scientists and farmers in touch with each other. The time to organise and facilitate such programs is something that Powell and Colin (2009) also noted in their review of participatory nanotechnology projects.

5.2.2 Participants

The CCP started with 34 farmers representing a range of enterprises, including beekeeping, grain growing, dairy, beef, fine wool, sugar, cotton, viticulture and horticulture. Farmers were encouraged to apply for the program through calls in the media. Participants were selected according to evidence of their understanding and interest in climate science and risk, their networks with other farmers, and their communication and leadership skills. Those selected were paid an honorarium of A\$4,000 per year and their expenses for travelling to workshops and meetings were also met through the program. Over the seven years that the program ran it involved 45 Australian farmers from all locations in Australia except for the Northern Territory.

CCP farmers met with scientific experts (climate, agronomic, social science) face-to-face at formal workshops, informal farm visits, and through the initiative of individual farmers and scientists. They communicated irregularly through email and

phone contact. Representatives from the sponsoring RDCs participated to a lesser degree in workshops and farm visits. While RDCs are recognised as non-government organisations, they are accountable to their farming sector and the government of the day, and therefore tend to be conservative in their approaches to communication. The CCP was considered by many of the RDC representatives to be a high-risk investment. While the CCP is an example of a sponsored participatory program (Bucchi & Neresini, 2008), individual scientists and farmers initiated their own activities in similar ways to activities occurring in unsponsored programs. From the first workshop in March 2010, CCP farmers were encouraged and supported to set their own objectives and design their own activities within the overall goals of the program.

5.2.3 Review and evaluation of the CCP

The CCP was independently reviewed or evaluated throughout the course of its implementation. In 2012, Agrans Research's evaluation found a conservative 1:3 cost to benefit ratio from the program which they attributed to: the development of leadership qualities amongst participants; the likely greater adoption of sustainable farm practices; the improved preparedness of industry to adapt to climate change; and the greater productivity gains that farmers would likely have due to improved research resource efficiency. This evaluation did not investigate the impact of farmers participating with scientists. Another review of the program by the Commonwealth Scientific and Industrial Organisation (CSIRO) in 2014 also did not investigate the participation of farmers with scientists, but found that the CCP was an:

...invaluable opportunity for learning about climate change and building a large and trusted network of producers from around Australia to share knowledge and learn new ideas on climate change adaptation through inquiry.

As a response to her involvement in the program, one dairy farmer set up a network of Young Farming Champions (<http://youngfarmingchampions.com/>, retrieved 6 February 2019), with the aim of building the leadership and communication skills of young farmers to engage in a range of issues including managing climate risk. The network has expanded since it was set up in 2010 and continues today to support young people involved in agriculture to have a significant voice in national agricultural discussions and debate. There is no doubt that CCP changed lives. It changed how climate science relevant to agriculture was done and communicated in Australia, and it helped to create a core of confident and credible farmers who are continuing to change others' lives.

A final review of MCV's communication completed in late 2015 noted the benefits for researchers from participating in the program (Coutts, 2015, p. 20-21):

This review highlighted that there has been good interaction between Climate Champion farmers and researchers at the annual forums and that some have had direct engagement outside this opportunity. The researchers (and Climate Champion farmers) interviewed were generally very positive about the interaction and valued the contact, with one researcher commenting that without them, researchers would struggle to find farmers to talk to - they are a great testing ground to determine the value and impact of tools.

Ironically, the success of the program in building the confidence of farmers through communication skills training and access to the latest scientific knowledge may have contributed to its ultimate demise. The supporting RDCs decided to reduce funding in 2013 and then terminate the program in 2016. This is likely to have been at least partly due to the increasing political activism of some of the CCP farmers. In the later stages of the program, a number of participants became leaders in the emerging Farmers for Climate Action group, who describe themselves as: "an alliance of farmers and leaders in agriculture who are working with our peers, the wider sector and

decision-makers to make sure Australia takes the actions necessary to address damage to our climate”. Five of the 24 farmers currently listed on their website, <https://www.farmersforclimateaction.org.au/> (retrieved 18 March 2018) were CCP participants. This move towards activism concerned the RDC representatives involved in the MCV program. The author of the 2015 review of CCP (Coutts, 2015 p. 20) noted:

There is a view by some [RDC representatives] that while the Climate Champion farmers themselves are benefiting from the program, their networks and areas of influence are too narrow to be an effective broad communication channel for rural industries. Some would like to see this program modified or ended and the resources allocated elsewhere.

While the rhetoric of this statement is about the CCP farmer’s perceived failure to extend research broadly enough across Australian agriculture (something that was never properly evaluated), other conversations I had with various actors involved or associated with the program appear to indicate that the CCP farmer’s increasing activism was perceived to be too risky for the conservative RDCs to continue funding the CCP.

5.2.4 My research

My research explores the interactions between CCP farmers and scientists against the predicted characteristics of the science communication models (see Chapter 2, Table 2).

In particular, my research investigates two questions:

- (1) To what extent are the theorised characteristics of the participatory science communication model reflected in the CCP?
- (2) What are the implications from the CCP case study for practitioners seeking to initiate long-term participatory science communication programs?

I investigate these questions by analysing: (a) the responses of scientists and climate champion farmers to online surveys; and (b) discussions between scientists and climate champion farmers captured during a workshop in 2014. Given I was involved in initiating, developing and managing the program, I have specifically chosen a workshop that was facilitated by people other than me to analyse.

5.3 Methods

Three sources of data were used in this study.

1. Responses from CCP scientists to qualitative survey questions collected online in 2013 (see Appendix C).
2. Transcripts from discussions between CCP farmers and scientists at workshop sessions held in 2014.
3. Responses from CCP farmers and scientists to qualitative and quantitative survey questions collected online at the end of the program in 2016 (see Appendix C).

5.3.1 Surveys of farmers and scientists (2013 and 2016)

I surveyed scientists about their involvement in the program in 2013 (see Appendix C) using qualitative questions and obtained 19 responses from those active in the program at that time. The questions are shown in Table 12. In the last month of the CCP (June 2016), I contacted all the Climate Champion farmers and scientists who had been involved in the program over the seven years and asked them to complete a short survey (see Appendix C). Participants could remain anonymous or have their responses excluded from the research, which none chose to do. The survey questions included a mix of quantitative and qualitative questions about their participation in the program

(see Table 12). The survey data included 32 responses from CCP farmers (nine were involved throughout the whole seven years; three for 5-6 years; 17 for 3-4 years; and three for one year or less) and eight from scientists who had been involved throughout most of the program.

Table 12 shows the match of survey questions to the predicted characteristics of science communication models. My research used a template analysis approach, which applies categories based on prior research and theoretical perspectives to thematically organising and analysing the data (King, 2004; Huberman & Miles, 1994). I analysed the qualitative data using a simple thematic content analysis of the data (Cho & Lee, 2014). I first used a deductive approach to analyse responses against the selected characteristics of deficit, dialogue and participatory models of science communication, as outlined in Chapter 2, Table 2. I then applied an inductive approach to identify any further characteristics, not present in the literature. The answers to the 2016 quantitative questions were assessed with descriptive statistics.

Table 12. Survey questions explored according to aspects of theorised science communication models

Characteristic	Questions of CCP farmers (2016 n=32)	Questions of scientists (2013 n = 19; and 2016 n=8)
Objectives		<i>Qualitative questions</i> 2013 <ul style="list-style-type: none"> Whether interactions with the CCP farmers resulted in changes to research and its intended outcomes?
	<i>Qualitative questions</i> <ul style="list-style-type: none"> Whether they had done anything different because of the CCP? Whether the project had resulted in any personal benefits? Whether the project had resulted in any benefits for Australia? What could be improved about the project? 	
Nature of interaction	<i>Quantitative questions</i> <ul style="list-style-type: none"> Level of interaction with scientists? Level of activity in providing feedback to scientists about draft tools and products? Whether there were enough opportunities to interact with scientists? (Plus answers to qualitative questions)	<i>Qualitative questions</i> 2013 <ul style="list-style-type: none"> How they interacted with CCP farmers? <i>Quantitative questions</i> 2016

Characteristic	Questions of CCP farmers (2016 n=32)	Questions of scientists (2013 n = 19; and 2016 n=8)
		<ul style="list-style-type: none"> • Level of involvement in presenting at CCP workshops? • Level of involvement in discussing their research with CCP farmers at workshops? • How much they requested feedback to draft research tools or products? • Degree to which they asked CCP farmers to input into their research? • Level to which they responded to inquiries from CCP farmers? • Level to which they invited CCP farmers to participate in workshops/conferences? • Level of involvement with the CCP farmers on an informal basis? (Plus answers to qualitative questions)
Relationship between actors	<i>Quantitative questions</i> <ul style="list-style-type: none"> • How willing they thought scientists were to listen to their views? • How responsive scientists were to their questions? (Plus answers to qualitative questions)	2013 <ul style="list-style-type: none"> • The expectations of the CCP farmers prior to participation with them, and what they expected? • Whether contact with CCP farmers met expectations and was satisfying? 2016 <ul style="list-style-type: none"> • How willing the CCP farmers were to listen to their ideas? • How responsive the CCP farmers were to questions asked of them? (Plus answers to qualitative questions above)
Knowledge	<i>Quantitative questions</i> <ul style="list-style-type: none"> • How they would rate the quality of information they received from scientists? • Whether they thought the scientists had done anything different because of the program? (Plus answers to qualitative questions)	<i>Quantitative questions</i> 2016 <ul style="list-style-type: none"> • How they would rate the quality of feedback from CCP farmers? • Whether they thought the farmers had done anything different because of the program? (Plus answers to qualitative questions)
Acknowledgment of risk	Qualitative questions analysed according to what risks are raised and how these are discussed	

5.4.2 Analysis of workshop discussions

The CCP initially had two to three workshops a year where CCP farmers came together in one location for discussions with each other, to interact with scientists, and to learn new communication skills. In the last three years of the program, due to budget constraints, this was reduced to one workshop a year. The 2014 annual workshop was held in Canberra and included a number of facilitated discussions between scientists and CCP farmers, usually after formal presentations. The discussions involved 11 scientists and 13 farmers. However, not all of participants attended all sessions, which were spread over three days. Some scientists were only there for the day they were presenting, and some CCP farmers were not able to attend the whole workshop. All workshop participants signed a form agreeing for their discussions to be used as part of my research. An analysis of six transcribed session discussions is included in this study (see in Table 13).

Table 13. Discussions analysed at the CCP workshop, March 2014

Topic discussed	Number of CCP farmers participating (No of comments)	Number of scientists participating (No of comments)
The use of the model POAMA	9 (16)	6 (22)
Heat and frost forecasts	5 (6)	2 (11)
Forecasts and decisions	7 (20)	6 (30)
Improved forecasts	3 (7)	5 (13)
Bureau of Meteorology products	5 (6)	2 (14)
Multi-model forecasts	5 (7)	4 (8)
TOTAL comments	62	98

I analysed the workshop transcripts to explore the nature of participation and the relationships between the actors involved in that participation. I used the four overall modes of participation identified by Kouper (2010) to code the data:

- (1) Contributing to the topic – e.g. reporting from an external report or source;
making an argument that adds to the topic, explaining more about the topic or
asking questions of clarification

- (2) Deviating from the topic – e.g. digressing, insulting, self-promotion
- (3) Expressing attitudes or emotions – e.g. approval, disapproval, regret, personal experiences, anger
- (4) Attempting to influence others' actions through advice, recommendations, requests and proposals.

I also thematically analysed the content of the discussions to ascertain how the actors jointly or separately were constructing the nature of risk associated with the climate science they discussed.

5.4 Results

5.4.1 *Actors' objectives for participation*

An analysis across all the 2013 and 2016 surveys' qualitative questions of what the CCP farmers and scientists valued about the program indicates what they hoped they would get out of the program. As Table 14 shows, both farmers and scientists had a mix of objectives across those predicted for all three models. However, there was less emphasis on some of the predicted participatory model objectives (e.g. joint problem solving, participation in policy making) and more focus on deficit objectives such as improving decision-making through increased knowledge and changing behaviours and attitudes.

Table 14 The objectives of CCP farmers and scientists that emerged from survey qualitative data compared to those predicted by theorised science communication models (X= mentioned a few times; XX = mentioned several times; XXX = mentioned by most respondents)

Objectives characterised by models	Farmers	Scientists
Deficit		
1. Raise awareness of science	XXX	X
2. Inform about science	XX	XXX
3. Correct misconceptions	X	XX
4. Gain support and funding for science		X
5. Promote careers in science		

Objectives characterised by models	Farmers	Scientists
6. Popularise science		
7. Educate in science	X	XX
8. Address concerns about science	X	X
9. Improve decision-making through increased knowledge	XXX	XXX
10. Respond to interest in science		XX
11. Change behaviours and attitudes	XXX	XXX
Dialogue		
1. Address mistrust in science		X
2. Discover public opinion about science to communicate more effectively	XX	XXX
	XX	XXX
3. Gain and use lay knowledge	XXX	XX
4. Debate / discuss scientific issues	XX	X
5. Connect with those from other disciplines	XX	XX
6. Be more accessible and accountable to public		XX
7. Engage public in decision-making		
Participatory		
1. Collectively learn	XXX	XX
2. Jointly produce new knowledge	XX	X
3. Jointly solve a problem	X	X
4. Participate with public in policy making		
5. Participate with cultural interests other than science		
6. Shape the research agenda	XX	XX
7. Critically reflect on science		

The farmers' strongest participatory-style objective was to 'collectively learn'. This connected with the qualitative theme that emerged of learning from each other, often on an informal basis. For example, a typical statement in response to the question about what farmers liked best about the program was: "Interaction with fellow farmers and top researchers about the effects of climate change and how best to manage and mitigate that without the negativity of local ill-informed views" (F1603- farmer who responded to the survey in 2016 who was labelled number 3). Another example was: "The interaction between other farmers and researchers, looking at the challenges together" (F1630). Six different farmers used the phrase 'like-minded' when referring to participation within the group, for example: "Interaction with like-minded farmers and sharing our knowledge and experiences in regard to the changing climate" (F1616). One of the benefits that many of the farmers thought they got from the CCP was participating with each other even though they were working in different industries in various locations across Australia. For example:

The most beneficial experiences for me was learning from other Farmers about how they are responding to climate risk, about their communication strategies and successes, and about their ways of negotiating information (F1619).

The participation of farmers with each other and the benefits they derived from that was an unexpected outcome of bringing farmers together with scientists.

Another perceived benefit from the program by about a third of CCP farmers was that it increased the profile and importance of climate to their peers and the wider community. One farmer said, “I consider it was starting to make a real impact - I was seeing graziers [cattle and sheep farmers] at workshops discussing climate change who would never have come previously” (F1607). Another said:

Helped raise the profile of climate change, with consistent clear and factual messaging. Assisted the uptake of information and tools to use forecasting and adaption tools to manage variability (F1628).

Participating with scientists was thought by some to help establish their own credibility in the climate space, for example, “Putting climate on the table and giving credibility to agriculturalists as voices for climate” (F1601). Establishing public credibility through the program was valued by a number of CCP farmers.

The scientists involved in the CCP valued the direct access that it gave to them to representatives of agricultural industries across Australia; the feedback they received about their research, its draft products and tools, and the way it was communicated; and interacting with a knowledgeable group of farmers. Their apparent objectives again spanned those predicted by the three science communication models (see Table 14). Similar to the farmers, their objectives most strongly reflected those predicted for the deficit and dialogue models. They particularly valued the opportunity to interact and discuss their research with farmers, which was often framed in the context of using the group for some specific purpose. For example, “As co-ordinator of a national CC

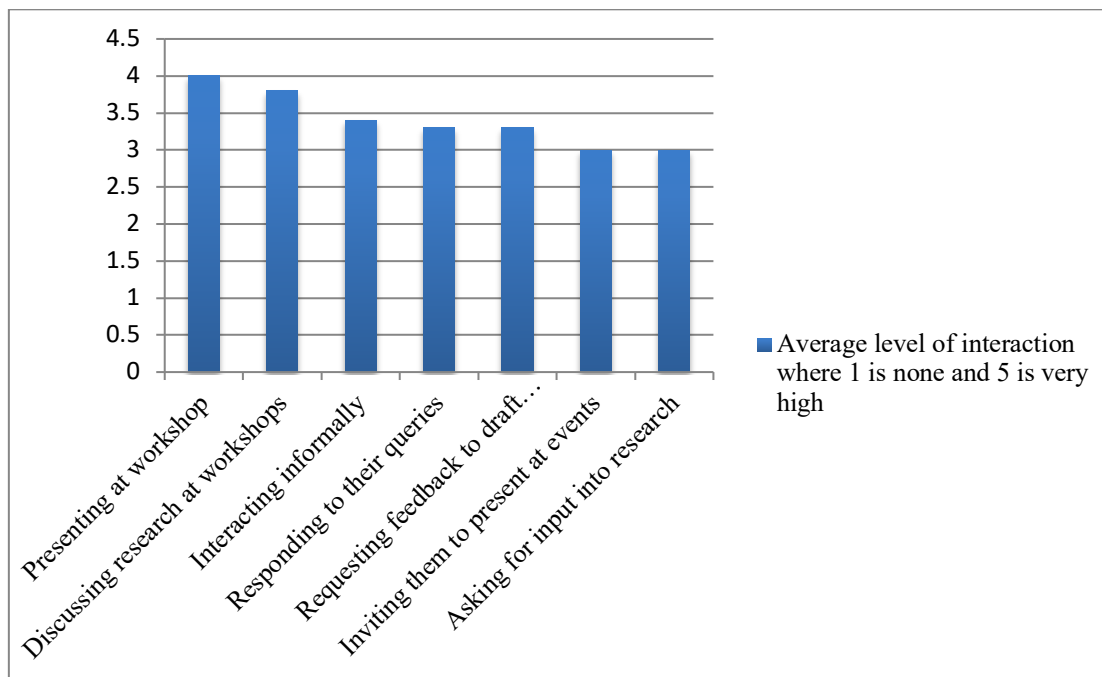
[Climate Change] Adaptation network it provided me with an extremely valuable industry-based network to tap into when we wished to interact with their particular industries” (S162).

5.4.2 Nature of interaction

In response to the quantitative survey questions, most CCP farmers reported a moderate to high interaction with scientists over the course of the Program. The more years that CCP farmers were involved in the program, the higher their interaction and activity. When asked if there were enough opportunities to interact with scientists the majority (26/32) said ‘just right’, with only six reporting ‘too little’. Four of those stating that they had ‘too little’ interaction had been involved in the program less than four years. No farmer reported that there was too much interaction.

The scientists’ reports on their level of involvement in the program are shown in Figure 1. Their highest level of interaction was at organised workshops, either presenting to CCP farmers or discussing their research with them at these forums. These results parallel the analysis of qualitative responses from scientists to the survey in 2013 with the majority citing workshops, presentations and discussions at workshops as being their primary means of participating with CCP farmers. These reported interactions align with those predicted for deficit and dialogue models, rather than participation. Seven out of the 19 scientists responding to the 2013 survey noted that they requested feedback from CCP to their research or its products, and a similar percentage were also interested in finding out about participants’ farm activities and use of information.

Figure 1. 2016 survey—Level of interaction of scientists with CCP farmers (n=7)



The analysis of the 2014 workshop discussion sessions between climate champion farmers and scientists indicate that more than half of the comments made by both farmers and scientists were contributing to dialogue through explaining, describing or questioning in relation to the topic. There was minimal deviation from the topics being discussed, and when there was it was a slight digression with no hint of participants being insulting or self-promoting. Farmers were more likely (about 30%) than scientists (less than 20%) to express an attitude in their comments. Such comments usually related to their personal experiences on their farms, and what this meant for them. For example, the following comment from CCP farmer F3 is typical:

The tools, we are using more and more in terms of [finding out about] soil moisture, type of soil we've got... But at what point do you stop getting more info? Takes a lot to stop. What are your options if you choose to do something if the forecasts tell you not to? We have a lot of [water] entitlements in our area – at what point do I start to sell our water? Sometimes you have to be brave to make the right decisions – some farmers get caught up in love of farming sometimes, so they don't manage their risk really well.

Scientists, on the other hand, made more statements than farmers that indicated that they sought to influence others. For example, the following statement from scientist S12 talking about seasonal forecasts and nitrogen management:

My understanding on nitrous oxide issues was it's basically an S-shaped curve, stayed fairly flat along the bottom axis until you reached the point where you had more N [nitrogen] than what the plant could physically take up. Once you got to that point the measurements went through the roof. Obviously, rainfall is one limiting factor, but I think we need to be more realistic about some of the other limiting factors – established population, stage of crop – and maybe apply less N and still produce the same crop but that's where we'll have a big impact with reducing emissions.

However, none of the scientists' comments indicated that they were motivated to tell farmers what they absolutely should do. Instead scientists appeared to be actively listening and asking questions, as demonstrated by the following exchange between one scientist (S7) and a CCP farmer (F5):

(F5): Can I just relate my experience last year. So, very wet winter. Our subsoil is chock-a-block full [of water]. So, the three-month forecast says Spring is going to be above average [rainfall]. So, I trotted off to the bank manager and said, 'if ever I'm going to put nitrogen on, it's going to be this year'. And he reluctantly lent me the money. And by the time I had the urea in the shed the forecasters came out and said that 'we have changed our mind on the spring forecasts and it might not be as good as what we had first thought'. So, I put out a small amount of urea. I barely got it incorporated and, in the end, I might have got my money back, I might have had a small loss, but that's the sort of decision making you have to put up with all the way through. If we could get more accurate forecasts, particularly weekly and multi-week forecasts, that would make a huge difference, rather than having that big gap that we were talking about before.

(S7): So [F5], you're making this decision in August?

(F5): Yes. Well, say July, mid-July.

(S7): You're ordering fertiliser in July. And you're putting it out in August?

(S7): So, you're in a very dry environment. So, there are plenty of people south of you who will be doing this as well?

(F5): Very much so. This is a one in 10-year opportunity that I thought had presented itself.

(S7): So, you would be after a six-week forecast? So, in that July-August period you are really interested in what is happening in the next 6 weeks?

(F5): Exactly and you are assessing the probabilities of success and that sort of stuff. But it all comes back to this accuracy. The accuracy is really paramount because you are really sticking your neck out for this quite often.

(S7): And forecasts that flip are a challenge.

(F5): Yes, and once you've been burnt by a forecast you are less likely to follow it

Much of the interaction between farmers and scientists in CCP appears to be linear – one-way or two-way communication involving just two actor groups—farmers and scientists. As such, communication is more reminiscent of the style described by the deficit and dialogue models rather than the participatory one. However, the dialogue between farmers and scientists is a genuine one where they are listening to each other, and openly expressing their views. Farmers share their experiences as a way of participating with scientists, and scientists use their knowledge to influence farmers' actions.

5.4.3 Relationships between actors

Two quantitative questions in the 2016 survey assessed the quality of the relationships between CCP farmers and scientists as perceived by each group. These questions investigated the willingness of each group to listen and respond to questions. Regardless of the length of time in the program, the CCP farmers rated scientists very high for both their willingness to listen (average of 4.3 where 1 is not at all and 5 is very willing), and their responsiveness to questions asked of them (4.2/5). The scientists who responded to the survey also rated the CCP farmers' willingness to listen (4.9/5) and

responsiveness (4.5/5) very highly. The positive nature of the perceived relationships between farmers and scientists also emerged from the qualitative data, with several saying their relationships had turned into friendships. For example, a climate scientist from the Bureau of Meteorology (S166) said his highlight from interacting with CCP farmers was “Meeting the real users of our bom [Bureau of Meteorology] products - hearing how they used it and what they would like to see from our work. But also, friendships made”. Likewise, several CCP farmers noted friendships formed through the program as a highlight, “The friendships formed and the understanding of issues right across Australia” (F1624). Many of these friendships have endured since the program, according to personal discussions I have had since with both farmers and scientists.

The scientists who responded to the 2013 survey mentioned their enjoyable and positive interactions with CCP farmers. For example, “Satisfying and enjoyable. I hope they got something from it too” (S131), and “The contact was very positive, and I am keen to explore further opportunities to meet with Climate Champions and have discussions about developments in the Bureau and get their feedback” (S134). Scientists responding to the 2016 survey rated their satisfaction with participating in the program very highly (average of 4.4 where 1 is very low and 5 is very high). When asked how the program could have been improved, both CCP farmers and scientists recommended even more participation between farmers and scientists. The CCP farmers also wanted more interaction with other farmers.

Analysis of the discussion sessions at the 2014 workshop indicates that scientists and farmers have developed relationships of mutual trust where they feel they can be open with each other and critically reflect on what is happening in science and in agriculture. For example, in the final discussion session a farmer (F11) asks the

scientists what the impediments are for achieving multi-model forecasting. A scientist (S2) responds by acknowledging a lack of organisational will “I think there is preparedness among many in the science community to work together. The ability to do that is frankly associated with the ability of their institutions to work together”. This reflects the sort of open and equal relationships typical of the theorised participatory science communication model or Irwin’s (2014) third order of thinking.

5.4.4 Knowledge

When CCP farmers were asked about the quality of information presented to them by scientists they rated the importance of this very highly (average of 4.2 where 1 is very low and 5 is very high). Likewise, when scientists were asked to rate the quality of the feedback that they received from CCP farmers, they rated the importance of this highly (average of 4.1 where 1 is very low and 5 is very high).

An analysis of the 2016 survey’s qualitative responses demonstrates how reciprocal knowledge was valued and used by farmers and scientists. One quarter of CCP farmer respondents (n =8) explicitly stated that their understanding of the climate science was improved through their participation with scientists. For example, when asked if they had done anything different because of their participation, a typical response was “Better understanding of forecasts, how they work and how to use them” (F1607). Others made reference to their use of the presented climate tools “I use POAMA [seasonal forecasting model] & other climate forecasting tools daily in my business” (F1606). The benefits for communicating with other farmers was also noted as a difference created from participating with scientists, for example, “My interactions with researchers gave me more confidence to converse with my farming peers about climate change due to the scope of evidence that exists in the scientific community” (F1614). Several CCP farmers thought the program and their interaction with scientists

created credibility for their own knowledge “It gave me some detailed knowledge when discussing climate change with my peers therefore giving my discussions greater credibility” (F1616). The CCP farmers thought that the scientists also likely valued their knowledge and inputs and they hoped that they did things differently because of it. As farmer F163 said:

It certainly appeared to give much needed feedback and strengthen their conviction about which track to be on and guide their priorities. We also benefited from customized focus on topics that we felt needed greater attention; e.g. probabilities.

Some CCP farmers referred to specific examples where research may have changed due their input, for example, “Heat tolerance in cereals now a major research focus” (F1609). CCP farmers perceived they were having a real impact on the science, which also improved their own confidence.

From the 2016 survey data relating to what scientists did differently as a result of participating with CCP farmers, I identified four groups of outcomes. Firstly, most respondents noted that they now had a much greater understanding of farmer needs. A typical comment was:

Terrific to see how the champs helped researchers or policy people better understand the needs of farmers. This was a great improvement to have willing and accessible champion farmers who were across climate issues but offered practical insights for what would be useful for them and other farmers (S167).

Secondly, the scientists thought that the CCP farmers’ feedback helped to shape their research tools and products, which reflects a substantive motivation for participation. For example (S166), “I altered the presentation/design of some of our experimental forecast products”. Respondents to the 2013 survey also noted specific changes they made as a result of interactions with CCP farmers. For example:

[Farmer X] provided excellent feedback that we will use to improve the tool. In particular, [Farmer X] pointed out that we had not presented the outputs (results) form in a way that was meaningful or easy to interpret by the intended users of the tool - extension advisors and sugarcane farmers and suggested some alternatives. As a result, we plan to significantly improve the output of the tool based on [Farmer X] feedback (S132).

Thirdly, some of the scientists recognised that CCP farmers' input helped to shape their research, for example, "My work on linking probabilities to decision making was encouraged and shaped through the interaction with the group" (S161). Scientists also noted that their own communication improved as a result of their participation with CCP farmers:

It has helped me improve the way I communicate to stakeholders... It has underscored to me the importance of good communication in terms of the uptake and utility of forecast products; feedback from the workshops has helped us to tailor our development of experimental forecast products, including the presentation of the product (S166).

Clearly, scientists who participated in the program are seeing both instrumental and substantive benefits from engaging with the CCP farmers.

A scientist who attended the entire workshop (S7) in 2014 reflected on the themes of the first two days of the workshop. He uses inclusive language and his statements indicate that scientists and farmers have learned from each other over the course of the workshop:

I'm hearing a lot of common themes... One is that there is a lot of information already available that not everyone knows about and knows how to interpret properly. So, I think it's important to find a mechanism where we can get the information out not just to you guys but to all farmers to explain the information that is not misleading but useful... The other theme I'm hearing a lot is the need for information at smaller scales than POAMA is providing. And I think that is an issue we have to deal with. How do we do the downscaling with the model that

we've got? Whether it is 250km or 75km in a few years; it's still not at your farm gate. So, I think we have to think about how we downscale the information.

As this quote illustrates, participants in the CCP respect each other's knowledge and see it as equally valid in jointly solving climate risk problems. However, scientific knowledge is still perceived as separate from the farmer's lay knowledge. Farmers and scientists did not indicate that they were co-jointly developing new knowledge to manage climate risks.

5.4.5 Acknowledgment of risk

The scientists surveyed (2013 and 2016) acknowledged there were risks that farmers needed to manage in making decisions about how to manage their enterprises in a variable and changing climate, and that scientists' role was to improve farmers' ability to manage such risk. Several also noted that their participation with CCP farmers helped them to better understand the nature of the climate risks farmers face. One scientist said his participation with the farmers reinforced the need to further examine climate risks as they relate to on-farm practice:

Most recent was around the balance of focus on managing seasonal and climate risk on farms. Need not only better forecasts, but better farmer literacy of climate for their region, and then the tools/tactics/ strategies to manage whatever happens (S168).

This quote highlights the perception by this scientist that better farmer literacy of climate is needed, reinforcing linear model approaches to science communication.

The CCP farmers noted that an important benefit of the program for both scientists and farmers was a better understanding of climate risk, for example, "Showed how regional differences and enterprises were reacting to climate and how to manage climate risk" (S169). Better knowledge of how to manage that risk was articulated by

some as a specific benefit of the program, for example, “A step towards helping a shift in industry attitude towards climate change/variability and individual ability to respond proactively with risk management” (S163). Climate risk was an overriding theme of the CCP and both scientists and farmers were open about the risks from interpreting research, and what that meant for managing risk within a farming enterprise.

This focus on climate risk was also reflected in the 2014 workshop discussions between scientists and farmers. Scientists had no hesitation articulating areas of uncertainty, indicating that they had developed trust in CCP farmers’ ability to respond and interpret such uncertainty. For example, one scientist said:

Last month I went to the first scientific conference focused on multi-week prediction. So, the world meteorological organisation has just recognised it as an area of prediction and a science that needs to be investigated. So, it is a really new field and a lot of the work we are doing is pioneering and it’s a really difficult time to provide skilful forecasting. The point I wanted to make is that these climate models can produce a whole lot of data and we could give you day-to-day data for the next month but that doesn’t mean you should trust it (S10).

This demonstrates an openness between participants that some scholars theorised was necessary for the participatory model. For example, Irwin (2008) discusses the need for open and transparent dialogue; Trench (2008) talks about science and its institutions being open to public scrutiny; and Bucchi (2008) suggests that participatory science communication also needs to be open to the notion of conflict.

Both scientists and farmers recognised that decision-making about climate risk occurred within the economic and social contexts that each farmer faces. For example, in a discussion about climate risk, one of the sponsors asked about how to communicate frost risk to farmers, and scientist replied “I think the only successful way to do that is to have farmer workshops. And so, having this regionalised, having the information in a

relevant context for the farmers in the room” (S4). As such, this reflects the theorised participatory model, at least in terms of the specific contextual challenges that farmers face in dealing with climate risk.

5.5. Discussion and conclusions

In this chapter, I set out to determine the extent that the theorised characteristics of the science communication models, especially the participatory model, are reflected in the CCP. This is important if we are to develop our science communication theories and models further using empirical evidence. It is also important for creating more useful connections between science communication scholars and practitioners. In this final section, I will address this aim and also present the implications of this CCP case study for scholars who theorise about science communication and for practitioners seeking to initiate long-term participatory science communication programs.

5.5.1 Participants in Climate Champion Program were motivated mostly by deficit and dialogue-style objectives

Farmers and scientists appear to be driven to participate in the CCP due to a mix of objectives spanning those predicted from theorised deficit, dialogue and participatory models. Objectives typical of linear communication (deficit and dialogue) are still strong motivators for both farmers and scientists. Scientists want to inform farmers of their science and increase farmers’ science literacy (in this case their climate science literacy). Farmers are demanding specific information from scientists, and the scientists participating in the CCP are willingly responding. Farmers valued gaining new knowledge as well as the heightened public awareness of climate science and agriculture that resulted from their involvement in the CCP. Both scientists and farmers want to improve decision-making (their own and others) through improved knowledge.

They want to gain knowledge from each other, and to jointly discuss scientific issues. While there was a desire by both scientists and farmers to collectively learn, a theorised objective of the participatory science communication model, it appears that both were still largely motivated by linear forms of communication.

There appears to have been less desire by all participants, or possibly opportunity, to jointly produce new knowledge or solve problems, as predicted in the theorised participatory model of science communication. This may be because knowledge was still framed as either science or lay in nature (Kurath & Gisler, 2009). Despite this, scientists and farmers expressed a desire for the research agenda to be shaped with input from all parties. As such, upstream engagement of CCP farmers in research appeared from scientists' responses to the surveys to have resulted in real changes to the direction and application of climate science. Scientists involved in CCP have modified their research, changed how they have packaged the products of such research, and improved the way they communicate about their research and its products on the basis of feedback and advice from the CCP farmers.

On the other hand, CCP farmers gained considerable confidence and expertise from their participation with scientists, and many felt more confident and credible to discuss climate science with their peers as a result of the program. This means the CCP also delivered capacity building to farmers, which is one of the recent themes of public engagement research (e.g. Guston, 2014; Selin et al., 2017). Providing *access* to scientists and their institutions was also one of the theorised objectives that was commonly found in the Australian national audit of science engagement activities. As discussed in Chapter 3, this objective resonates with the term 'capacity building'. This development of farmers' skills and capacity to engage happened due to the long term nature of the program. As Powell and Colin (2009) noted:

Most participatory exercises do not engage citizens beyond an event or a few weeks/months, and they do not build citizens' participatory skills in ways that would help them engage with scientists or policy makers independently" (p. 2009)

This study of the CCP demonstrates that those involved in such participatory science communication program may have a mix of communication objectives for their participation, including those predicted for deficit and dialogue communication. However, having such a mix can still achieve the desired changes and solve the problems that participatory communication is predicted to achieve.

5.5.2 Climate Champion Program reflects a mix of theorised characteristics of all three science communication models

The mix of science communication styles present in the CCP is demonstrated further through my analysis of the nature of the interactions. While there was plenty of two-way interactions happening between scientists and farmers typical of those predicted for the dialogue model, scientists were still using formal presentations at workshops to provide information in a one-way format typical of deficit-style communication. The traditional role of 'speaker' in the CCP was more often than not given to scientists rather than to the farmers, which has also been found in other research on participatory science communication initiatives (Kurath & Gisler, 2009). To some extent, scientists still dominated discussions as shown in Table 13 where scientists made more comments than farmers during discussions. Despite this, there was critical scrutiny by the CCP farmers of the presented scientific research and its products, unlike the concerns noted in other research about this not happening (e.g. Hagendijk & Irwin, 2006; Kurath & Gisler, 2009). This scrutiny did lead to instances of scientists changing their research direction, and how they packaged and communicated about their research outputs.

Interestingly, it was not just farmers learning from scientists or vice versa; the program resulted in farmers learning from each other, and scientists also learning from each other. In that sense, interactions were happening in multiple directions between multiple actors, as predicted by the participatory model.

5.5.3 Respectful, trusting and open relationships result from long term participation

While the CCP participants' motivations and activities may have been largely linear in nature, participation over a significant period of time resulted in respectful, trusting and open relationships between farmers and scientists. They valued each other's knowledge; there was a perceived mutual benefit from listening to and learning from each other; and they enjoyed interacting with each other. Farmers were more likely to have shared personal experiences, and scientists to have attempted to use their knowledge to influence farmers' actions, but both groups were prepared to be open with each other and to frankly discuss scientific and lay uncertainties. Such openness indicates trust had developed between farmers and scientists participating in the program.

Scholars from many different fields including psychology, communication, marketing and risk study trust (Siegrist, 2010), and generally identify two broad types of trust—general trust and interpersonal trust. People have general trust in people they don't know based on their confidence in a known social structure (Sofranko, Khan & Morgan, 1988). Interpersonal trust is based on personal interactions and relationships (Siegrist, 2010), and is relevant to this study. Earle (2008) defines trust as a willingness to be vulnerable to someone else's judgment based on seeing them as having similar intentions or values. For example, Marquart, O'Keefe and Gunther (1995) surveyed 500 dairy farmers about their perceptions of risks in using hormones on their farms. They found that expertise does not affect people's perceptions of trustworthiness, although

attitude similarity does. Perhaps through their participation with scientists, CCP farmers are developing similar attitudes through their relationships with scientists. Carolan (2006) studied the rise of sustainable agricultural with Iowan farmers and postulates ‘the local’ concept, where networks of trust and knowledge are continuously used, adapted and negotiated. Regular face-to-face and phone and email interactions between CCP farmers and scientists means there was likely a regular renegotiation and deepening of trust based on individual actions and speech. When Carolan (2006, p. 331) examined farmer field days, he found that not only was knowledge being:

...conveyed and nurtured at these field days; so too was trust. This trust was not the inactive, passive, “as-if” variety, however. Rather, it was an active trust, built upon the sustained intimacy of social networks and those individuals embedded within those networks.

The interaction between the farmers and scientists in the CCP at farmer field days and workshops appears to have created a similar trust between program participants.

Establishing trust through personal relationships is a crucial part of farmers being able to adapt to climate (Meinke et al., 2006) and to adopt new technologies (Pannell et al., 2009). This was something also found by Jason Major (2017) in his PhD thesis studying farmer decision making around weed and invertebrate pest management:

To encourage farmer participation in research, extension [communication from scientists to farmers] will need to build effective and interconnected relationships that are long-term and built on community trust. Extension has to focus less on the knowledge it wishes to impart and more on understanding the people with whom it needs to engage, the dynamics of that relationship and those with whom it interconnects. It is the relationship that generates new understanding and knowledge of a problem. (p. 264)

Trust built through participation also means people are more likely to trust and apply the information and knowledge they get from the trusted sources (Carolan, 2006;

Gregory & Satterfield, 1999; Hujala & Tikkanen, 2008). This means deficit-style communication is likely to be more effective if it happens between people who have developed relationships through participatory-style science communication, like for the CCP. This finding is backed up by other research into how science information is understood and applied. For example, Jacobi et al. (2011) found that if science communication happened between those in a trusting relationship, there was a much greater chance of science information being understood and used. They also suggest when trusted sources of information are used it decreases the time it takes to disseminate information.

Trust was established relatively early in the CCP, which possibly reflects other research showing that Australian farmers trust scientists more than politicians or government representatives (Buys et al., 2014). Trust was maintained and further built due to the long-term nature of the program. Tang et al. (2012) looked at public participation with scientists over a long period in surgical simulation exercises. Their research pointed to a ‘shared immersion model’ of science communication where the relationships of trust were built cumulatively and iteratively. The shared experience:

...encourages mutual trust between all parties, rebalancing the power gradient that often exists between ‘experts’ and ‘non-experts’ and opening the researchers’ thinking to unexpected insights from fresh eyes outside their field.

The CCP demonstrated such an immersive experience especially between the farmers and scientists involved throughout the program. In some cases, the immersive experience also led to genuine and on-going friendships between at least some of the scientists and farmers.

5.5.4 Participatory communication results in more effective deficit and dialogue-style communication

The quality of relationships that developed through participation in CCP may be the

main reason why deficit and dialogue-style communication was perceived by both farmers and scientists to be so effective: generating a high profile for climate change; delivering consistent and clear messages; changing research design, products and communication; and increasing adoption by farmers of seasonal forecasting tools. This likely reflects that the context for communication in the CCP was positive and collaborative from the start, where farmers and scientists were supported to come together to shape a participatory program jointly for mutual benefits. This is unlike the more toxic contexts surrounding high profile cases in the United Kingdom like mad cow disease and the impacts from the Chernobyl nuclear disaster on Cumbrian sheep (Wynne, 1989).

With mad cow disease the context was where scientists and national government representatives sought to reassure the public about the level of risk from eating meat without good evidence or any consultative or participatory processes. Likely they, similar to the scientists and government officials communicating with farmers about the restrictions caused by the Chernobyl disaster, underestimated the public's ability to handle risk. Wynne (1989) in discussing the Cumbrian case study said scientists held "a deeply embedded scientific assumption—amounting to a general stereotype— about lay people... they cannot handle uncertainty and risk and thus need to have technical information 'simplified'" (p. 37). Wynne (1989) also discussed how scientists failed to find out the local knowledge of the sheep farmers and integrate that into their scientific knowledge. This meant that their advice to sheep farmers and governments was not relevant to the realities of hill farming in Cumbria, or the local landscape. In analysing this case study 30 years ago, Wynne (1989) called for better relationships between scientists and publics, "Effective communication between technical experts and lay people thus requires them to restructure their regular social relationships" (p. 37). It was

cases such as these that led to calls by scholars and policy makers for the deficit model to be abandoned in the first place (Dudo, 2012; Powell & Colin, 2009; Wynne, 2006). Since then, many other scholars have noted the failure of linear communication to achieve desired outcomes of attitudinal and behavioural change, especially in the climate change space (Grant, 2016; Roberts, 2013). However, with the relationships developed in the CCP, participants appeared to be much more prepared to communicate openly with each other. Scientists perceived the CCP farmers to be competent enough to understand their uncertainties and to not misinterpret their messages.

For the CCP, a culture of trust communication enabled by a participatory approach allowed for more effective knowledge / information transfer and dialogue between scientists and farmers. This finding raises the question about how science communication models have been theorised to evolve. Generally, as already discussed in this thesis, the movement of deficit to dialogue to participation is one of progress, but what if real progress happens when participatory communication opens up real possibilities for more effective dialogue and deficit style communication? Another question to consider is whether trust built up through participation might ultimately lead to a decrease in participation, as everyone trusts each other to individually ‘get on with the job’?

5.5.5 Towards more robust science communication models

As discussed, participatory communication programs, where relationships develop over a significant time period, are likely to make linear communication approaches more useful and effective. Within the context of publicly contested science, instead of participation being the desired evolutionary end-point of theorised science communication models, it may, in fact, be the necessary foundation for deficit and dialogue approaches. Rather than deploring the limitations and failings of the theorised

deficit and dialogue models, scholars could do well by examining the contexts in which linear communication approaches are effective, and even demanded by the actors involved in science communication.

The CCP demonstrates the likely need for a mix of communication-styles to exist in participatory science communication programs. This is particularly true of science communication about publicly contested science. Relationships of trust develop through on-going dialogue. Such relationships result in more effective knowledge and information exchange.

On the flip side, it's difficult to obtain the full benefits of participatory and upstream science communication without including linear communication techniques of creating awareness, providing the best available scientific knowledge, and having an on-going dialogue. These conclusions parallel those few scholars who have also compared the theory and practice of science communication (Brossard & Lewenstein, 2010; Jensen & Holliman, 2015). As such, scholars should consider how participatory models of science communication could support and incorporate rather than move beyond linear communication models. While some scholars acknowledge the likely overlap between science communication models in practice (e.g. Bucchi, 2008), there has been little further theoretical consideration of how such findings in practice might shape or evolve new models of science engagement.

In the CCP, participants learnt from each other for mutual benefits, but there did not appear to be participation in the co-production of new knowledge. This does not seem to have been necessary for achieving the desired outcomes of the program, such as more reflexive research processes leading to farmer-relevant climate risk knowledge and products. Likewise, keeping scientific and lay knowledge separate did not hinder participants from genuinely and positively learning from each other, and thus enhancing

their own knowledge and activities. Theorists might consider more where co-production of knowledge is necessary, as opposed to a focus on benefits derived from developing genuinely open, trusting and respectful relationships.

5.5.6 Applications to the practice of science communication

As an example of a long-term participatory science communication program, the CCP provides important insights for practitioners. Chilvers (2008, p. 472-3) says that when participatory models are put into practice they need to focus on: “(1) staging engagement early and throughout the process; and (2) integrating and breaking down the distinctions between scientists, public and stakeholders”. Engagement between CCP farmers and scientists started from the beginning of the program and as many opportunities as possible were created throughout the program for continual interactions. However, the on-going participation between farmers and scientists did not lead to a breakdown in the distinctions between them or their knowledge sets. Instead, it was more important for achieving the outcomes of the program that farmers and scientists were enabled to develop relationships of openness and trust.

The science communication practitioners supporting the CCP created the opportunities for the farmers and scientists to interact, reflecting a mix of deficit, dialogue and participatory approaches. This was a result of deliberative communication strategies, which some scholars (Besley & Nisbet, 2013; Dudo, 2012; Dudo & Besley, 2016; Powell & Colin, 2009) identify as being essential for participatory science communication. In this sense, the science communicators involved in the CCP acted as necessary ‘boundary spanners’ (Jacobi et al., 2011) to bring scientists and farmers together and provide opportunities for deliberation about climate risk. They purposively stepped back and allowed the actors in the participation to articulate their needs, develop their own objectives, and establish their own relationships. However,

organising and facilitating such participatory processes can be very time consuming and expensive. After reviewing nanotechnology participatory projects, Powell and Colin (2009) concluded that:

Significant institutional support and incentives should be provided for organizers and scientists to actively engage with citizens, and participatory projects should include engagement training, capacity building, and incentives for citizens, organizers, and scientists (p. 341).

The CCP purposively provided training to farmers in media, presentation and climate change communication skills. The Program also included incentives for farmers and scientists to participate with each other, however this was more often than not merely the opportunity to meet together to discuss issues of mutual interest.

While scientists were from different disciplines and farmers were from different regions and industries, the CCP ‘concerned group’ was essentially limited to two participative groups—farmers and scientists. The program would have benefitted from the inclusion of other concerned actors from agribusiness, banking and rural health. Warner (2008, p. 764) discusses the value of knowledge from all the various actors involved in agricultural change being shuffled “from field to lab to market to society and back again, leaving no actor or knowledge unchanged”. The limitation of the CCP to just scientists and farmers means that there was less opportunity for the predicted objectives from the participatory model of jointly influencing policy-making or participating with cultural interests other than science to materialise. Science communicators setting up participatory programs should consider approaches that include a diversity of actors within the ‘concerned group’.

A strong theme of the discussions between scientists and farmers was the need to interpret climate risks for farmers according to their commodity, location and enterprise. This reflects the predictions of the theorised participatory model. However,

there was less explicit discussion of how people's values impact on perceptions of climate risk and consequent decision-making. Science communicators should facilitate such discussions of participants' values as part of the participatory process. This will likely be most effective once trusting relationships have been established between participants. This indicates again the importance of investing in long-term participatory programs when the science is publicly contested.

5.6 Concluding remarks

My analysis of the Climate Champion Program further reinforced the findings of the previous two chapters about the mix of objectives and characteristics in practice that exist between the three theorised models. However, it also went further than the previous two chapters to discover that participatory science communication activities may also be assisting deficit and dialogue-style activities to be more effective in communicating about climate science. In this sense, not only does participatory science communication possibly need to incorporate deficit and dialogue approaches at times; it can also support these approaches to be more effective.

At the heart of all of this, the CCP demonstrated that it is important that participants in a participatory program are supported to develop ongoing relationships of trust. It is these relationships which can provide the foundation for successful science communication.

These findings have implications for scholars modelling science communication. How can they incorporate the relationships between a mix of approaches to science communication with a consideration of the foundational importance of relationships? My next and final chapter brings together the findings from all my research to explore new visualisations of science communication models, and to discuss the implications of my findings for practitioners.

6. Towards a new model of science communication with implications for practice

As this thesis discusses, scholars have variously described different models of science communication over the past 20 years. This has paralleled an increasing emphasis by science communicators and policy makers for more deliberative public engagement with controversial science. I explored in depth the literature on science communication models and identified a range of possible objectives and characteristics that were theorised by a diversity of scholars to be present in the three dominant models of science communication. The wealth of information theorised about the three science communication models was then put into a framework that I could empirically test with practice case studies, the last two of which focused on climate change science, a publicly controversial issue in Australia and other countries like the USA and UK.

The aim of the research presented in this thesis was to explore how the practice of science communication, especially communication about science that is publicly controversial, reflects the theorised science communication models. This research addresses a significant gap in scholarship as to date there has been little empirical comparison of the theorised science communication models against practice.

My first case study analysed the characteristics of the 2012 Australian national audit of 415 science engagement activities. I analysed the descriptions of these activities provided by science communicators at one point in time. The next case study built on the audit's findings by examining commenters' engagement with two oppositional climate change science blogs—www.skepticalscience.com and www.joannenova.com. In this way, I was able to examine the dialogue that was happening on a controversial issue. Finally, I looked at a seven-year case study—the Australian Climate Champion Program, where scientists and farmers jointly addressed the problem of climate risk.

These three practice arenas were chosen because: there has been no research comparing the theorised models with a national record of science engagement activities; there has been very little research into how blogs on a controversial topic work as a dialogic tool between the commenters engaged with them; and most research into participatory science communication programs has focussed on one-off short-term events rather than a longer-term agenda of participation.

Analysis of the audit indicated that there were very few activities about controversial science, despite issues like climate change, environmental protection and new technologies being debated nationally, and often very politically, in Australia. The activities that were controversial in nature were more likely to demonstrate participatory characteristics; for example, engaging publics deliberatively in problem solving or producing reports. However, only a few activities out of the 415 analysed demonstrated more deliberative characteristics from either dialogue or participatory models, including activities such as discussing public opinions, gaining lay knowledge, debating issues or helping people make decisions. This has to be of some concern to Australian science institutions and science communicators.

The research presented in this thesis found that for all practice case studies, most science engagement activities had objectives and characteristics that reflected a mix of those theorised for deficit, dialogue and sometimes participatory activities. However, my thesis went beyond confirming the coexistence of the models to explaining more about how and why they coexist. Deficit model communication more often than not coexists with that of the dialogue model as science communicators converse with publics about their lectures, publication or exhibits. Dialogue model communication coexists with deficit model styles as the dissemination of information is often important for stimulating conversations or initiating consultations. In my analysis of the 2012

audit activities, participatory style communication always had characteristics from the other two models; it never existed by itself. This coexistence of models in practice appears to be not merely an unintentional lucky accident but a necessity for science communication activities to achieve their objectives. The models proposed by scholars to date do not fully take into account the extensive nature and mix of objectives for initiating or participating in science communication activities.

The importance of developing trusted relationships between participants for achieving the desired outcomes of all the theorised models of science communication was demonstrated by the Climate Champion Program case study. Participants in this program investigating the controversial topic of climate risk were much more open with each other, including when acknowledging uncertainties. Scientists changed the science they did, the shape of their research outputs and how they communicated about those outputs as a result of their involvement in the Program. Trusted relationships developed through participation also appear to make dialogue and deficit style communication more viable. This is a fundamental change to how many scholars have perceived the evolutionary nature of science communication models—from deficit to dialogue to participatory forms of engagement.

The research presented in this thesis helps further our scholarly understanding of how theorised science communication models might be shaped and adapted to better reflect and even influence practice. In this chapter, I bring together the results of the case study research and discuss their cumulative implications. I also discuss some adaptations to the existing science communication models, which seek to visualise the overlap between the three models and the breadth of objectives that may emerge in science engagement activities. I propose a new ‘nexus model’ for science communication and describe how this can be implemented within the practical contexts

of considering the objectives for engagement, who is involved in the engagement activity, and how positive relationships can be fostered among those participating.

6.1 Science communication models and practice—predictions and reality

My research findings are discussed below and grouped according to significant themes: communication objectives, actors and the nature of engagement, the co-existence of models in practice, and the role of controversy.

6.1.1 Objectives for science communication

Before commencing the empirical research, an exploration of the literature on science communication models identified a range of possible objectives and motivations that were identified by a diversity of scholars to be present in the three models of science communication (see Chapter 2, Table 2). This exploration of papers from many scholars uncovered a previously unrecognised breadth of possible science communication objectives for each model, which no single scholar has recognised to date. However, after collating the predicted objectives for science communication models across all of the literature, I identified only three additional objectives from the Australian audit data: one was a deficit-style communication objective ‘to promote a particular scientific institution or organisation’; and the other two were participatory-style objectives to ‘participate in a research endeavour with scientists’, and to ‘get lay people involved in gathering data or doing research’. The first of these additional objectives reflects the overall dominance of ‘promotional’ objectives among Australian engagement activities. From my review of the existing literature, the prevalence of these objectives seems to be underestimated by scholars. The last two additional objectives reflect the rise of activities associated with citizen science that directly involve people in doing the science, often with scientists. Interestingly, the objectives that were the least prevalent

(less than 1%) in the audit data were to: 'increase people's trust in science', and 'address people's concerns about science and scientists'. No activities appeared to be motivated to 'shape the agenda of science' or to 'critically reflect on science and its institutions'. This could be because such activities are not recognised as science engagement or communication activities, but it could also truly reflect a paucity of such activities in Australia. Given the time and cost of organising and facilitating such participatory activities (Powell & Colin, 2009), this is possibly not surprising.

The motivations of commenters who engaged in the blogs is not possible to determine from textual analysis, however, many expressed their desire to converse with like-minded people on topics they were interested in. Blogs are inherently dialogic tools, however the analysis of the comments also indicated a strong desire, expressed by many commenters, to disseminate information and educate others. These objectives are more reminiscent of those predicted by the deficit model. Scholars who have looked at the motivations of science bloggers, as compared with commenters, likewise found they had a desire to discuss or converse with publics about their findings and increase understanding of their science (Schäfer, 2012; Trench, 2012). However, in Trench's review of science blogs (2012), he also found that bloggers wanted to get feedback about their science, something that was not evident in the analysis of the comments of the blogs I examined.

Through an examination of a deliberatively participatory science communication activity, the Climate Champion Program, I found that the motivations of the scientists and farmers involved spanned those described for all three science communication models. Surprisingly, both parties expressed a strong desire to achieve objectives more typical of linear science communication models. While scientists and farmers wanted to collectively learn, they placed less emphasis on other predicted objectives associated

with participatory models; i.e. to jointly produce new knowledge or to solve problems. Despite this emphasis on linear objectives, farmers involved in the CCP were engaged upstream in the science and their feedback changed what the scientists researched, and how they shaped and communicated the outputs of that research. In the process, the farmers also gained the confidence and knowledge they needed to better manage their climate risk and to communicate this effectively in interactions with their peers. It appears from the CCP example, that the objectives of a participatory science communication activity do not need to be exclusively those predicted by the science communication models. Such activities can include a mix of objectives across all three theorised models and still achieve their desired outcomes.

6.1.2 Actors and the nature of their engagement

Through an analysis of the existing literature, I identified the particular actors theorised for each of the three science communication models; the different nature and timing of their interactions; the methods used by science communicators to interact with various publics; the varying relationships of power between the actors; and the differing ways that knowledge is viewed, and risk acknowledged (see Chapter 2, Table 2). In summary, deficit model communication is theorised to be one-way from scientists or science communicators to publics usually through mass communication means such as lectures and publications through a process where scientists are assumed to have all the important knowledge, and any risks to that knowledge are not acknowledged. Dialogue model communication is theorised to be two-way between scientists or government representatives and publics using tools such as citizen juries or opinion polls, where publics are acknowledged to have useful information that could help the scientific process and understanding of risk. Participatory communication involves scientists along with multiple publics communicating equally in many different directions through

tools like workshops and meetings according to the problem being explored and the social contexts.

The *Inspiring Australia* program audit analysis showed that most of the recorded activities featured both deficit and dialogue-style activities, which is likely not surprising given that over a third of the activities were about a one-off event, show or meeting with the overarching purpose of providing publics with access to science. As theorised in the science communication models, most of these events were driven by science communicators with science being the most valued source of knowledge. The activities that were more dialogic in nature tended to support simple interactions rather than consult publics or attempt to gain their knowledge. These findings reinforce those from scholars who postulate that such linear engagement aims to increase public acceptance of science rather than opening it up to scrutiny or acknowledge other forms of knowledge (Hagendijk & Irwin, 2006; Irwin, 2006; Kurath & Gisler, 2009; Trench, 2008).

The commenters involved in the climate change blogs appeared to use their comments to provide new information or knowledge, or to express an attitude. These uses reflect activities associated with deficit-style communication. The blogs seem to create and maintain their own publics as commenters sought and reinforced information congruent with their own views. Warner (2002), in his essay on publics and counter publics, argues that “A public is a space of discourse organised by nothing other than discourse itself” (p. 50). The commenters on the blogs I examined appear to create and organise such a space by paying attention to bloggers and commenters who reflected their own points of view. Commenters on both blogs would quickly act to shut down any dissenting commentary, further creating distinctive and separate publics through their “reflexive circulation of discourse” (Warner, 2002, p. 62). While blogs can be used

as communication tools to create dialogue, my analysis of commenters' conversations on two polarised climate change blogs indicated that most comments were deficit-style in nature with commenters proclaiming or disclaiming and not really listening to the views of others. The contractive nature of discussions (White, 2003) meant little dialogue was happening and resulted in these blogs creating their own insular publics. This process does not appear to be represented in any of the theorised science communication models.

The Climate Champion Program used a mix of activities across the predicted spectrum of science communication models. While scientific and lay knowledge sets remained separate, and scientists dominated conversations, there was still critical scrutiny by farmers of the science that was done and how its outputs were packaged and communicated. Co-learning, as predicted in the participatory science communication model, happened in multiple directions between all the actors involved, including between scientists of different disciplines and farmers representing different industries. The most important characteristic identified in the CCP, and not predicted specifically by the theorised models, was the development of respectful, open and trusting relationships between all those involved. It was these relationships, developed over a long time period and involving multiple formal and informal interactions, that resulted in positive changes. Such iterative relationships based on a series of successful interactions appeared to create a culture of trust, which seemed to enhance the deficit and dialogue style modes of communication that were also frequently used throughout the program. The theorised science communication models have largely ignored the role and power of trusted relationships, built through participatory communication, that can make deficit and dialogue-style communication more effective, which may explain why science communication models appear to coexist in practice.

6.1.3 Coexistence of models in practice

The audit along with my analysis of the Climate Champion Program, and to some extent the climate blogs, showed that the three models of science communication can coexist in practice. At the very least, it is difficult to separate the models in practice into three distinct groups. It is very rare for a science communication activity to reflect just the predicted deficit, dialogue or participatory communication characteristics. This appears to be true even when the overt objectives of the organisers of an activity are explicitly focussed on one model. For example, the motivations behind the Climate Champion Program were participatory, but the participants involved actually engaged with one another in ways that were characteristic of all the models, especially deficit and dialogue. The investigation of the 2012 national audit activities actually found that participatory model characteristics are more likely to be linked with deficit model characteristics than with dialogue. This suggests that participatory style communication also requires deficit style communication for it to work or that participatory style communication supports more effective deficit style communication. I argue that both are likely to be true. In a participatory science communication program, it is highly likely that participants will want to receive the latest expert knowledge on a topic of relevance. Likewise, as the analysis of the Climate Champion Program showed, in participatory programs relationships of trust develop between participants meaning that deficit-style communication is likely to be more effective and less likely to be misinterpreted.

While this concept of coexistence is not new and other scholars have discussed this phenomenon (e.g. Brossard & Lewenstein, 2010; Bucchi, 2008; Hetland, 2014, Jensen & Holliman, 2015; Trench, 2008), it has not been recognised in the literature as ubiquitously as I found in analysis of practice. A dominant notion in the literature is

rather one of distinct and evolving science communication models (e.g. Höppner, 2009; Palmer & Schibeci, 2012; Stocklmayer, 2013). Instead, my research found that it is likely to be necessary for the models to coexist in practice for that practice to achieve its objectives.

To take this idea of natural coexistence further, I found that even when the overall intent of a science communication activity was to convey information in one direction as per the deficit model, it was highly likely that at least simple dialogue between science communicators and publics was happening. For example, a commonly stated motivation for the engagement activities recorded in the audit was ‘to transfer information’. This was in response to a specific qualitative objective asking respondents what significant issue, need or priority their activity was addressing. However, when looking at their responses which described their activity, it was clear there was also dialogue-style activities happening, for example, “the talks series we hold allow the general public to hear *and chat* with practicing leaders in Australian science”. The publics attending these talks were not only listening (deficit), they were also conversing with the scientists (dialogue), and this was typical of many of the audit’s activities.

In reflecting about this coalescing of deficit and dialogue-style communication further, it’s probably not surprising. When the ‘great men of science’ gave their big science lectures in the 19th Century, it is very probable that they engaged in conversations with people before, during and after the event. Moreover, audience members were likely to be attending such lectures in the first place because they were interested in the science and ideas being presented; not because they or the scientists believed they had a deficit of knowledge that needed filling. Likewise, the motivations of modern science communicators may be primarily science literacy based, but it is also likely, especially with interested and possibly ‘already converted’ publics that they are

engaging in at least a simple dialogue in responding to and acknowledging the demands of their publics. This natural coexistence of science communication models in practice appears to have both an instrumental and normative basis.

My analysis of audit activities indicated that when the characteristics of the dialogue model are shown to be there in practice, they are usually alongside deficit and sometimes participatory-style characteristics. My in-depth analysis of blogs as a common modern dialogue tool also demonstrated that dialogue means of communication coexists with particularly deficit, but also very occasionally participatory styles. My analysis of the Climate Champion Program demonstrated that the predicted objectives and characteristics of all three models not only coexist in a participatory science communication activity, but also work to enhance the likelihood of achieving the mix of participants' objectives. Participatory-style activities were found to help develop relationships of trust, which meant scientists and farmers could more effectively share knowledge and acknowledge risks without misunderstandings resulting. My findings show that sharing of knowledge through deficit and dialogue-style activities within this context often led to more productive participation. In such a program, the coexistence of models in practice is not merely an unintentional lucky accident but a necessity for the program to achieve its outcomes. These findings are contingent on one participatory case study, and it would be valuable to examine if other participatory programs function in a similar way. Does participatory science communication always enhance trust between participants, or are there cases where trust actually decreases?

In the case of the CCP, the coexistence of the models in practice resulted in a core of farmers with better knowledge and tools for managing climate risk, and the confidence to communicate about these to other farmers. The scientists involved in the

program gained a better understanding of the context of their research and obtained the feedback they needed to better shape their research and its products according to the needs of farmers striving to manage their climate risk. These outcomes demonstrate that a participatory science communication program can help solve the problem of managing climate risk for farmers, but to do so participants in the program needed to employ all forms of science communication, encompassing deficit, dialogue and participation.

6.1.4 The role of controversy

The audit indicated few activities directed at controversial issues, which is a surprise given the public and political focus in Australia on issues such as climate change. However, those few activities that focussed on controversial issues also adopted methods associated with participatory models, as predicted by the scholars included in my review of the literature. These participatory methods were more likely to be used for controversial rather than for non-controversial activities.

My analysis of two antithetical climate change blogs showed that when the science topic is publicly controversial, conversations will start to resemble the predicted characteristics of a deficit-style approach to communication where a few commenters dominate and preach their messages, whether it be pro-science or anti-science. When dialogic tools like blogs are used over a sustained period of time to communicate about controversial issues, they appear to further polarise opinions as they create and maintain their own publics who are largely conversing using deficit style communication practices.

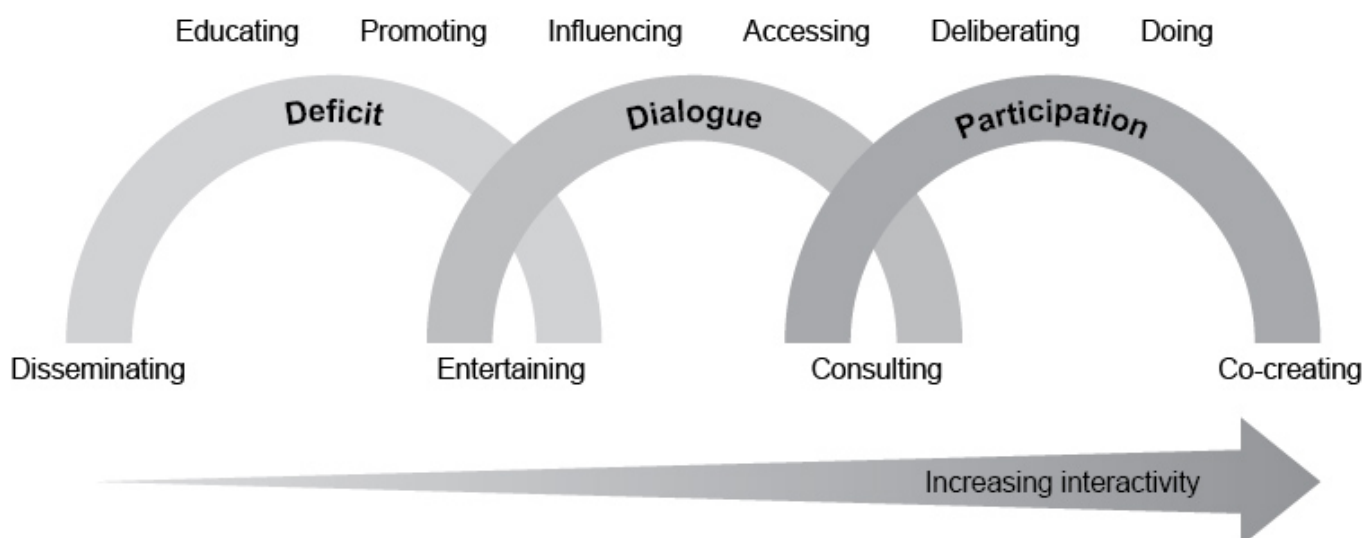
The results from analysing the CCP example demonstrate that for such participatory science communication programs to be effective, participants need to develop trust between each other. This relies on science communicators providing continual opportunities for participants to develop relationships over a significant period

of time. This contrasts with the polarised climate blogs where anyone with a differing view who enters one of those blogs is actively shut down. In such blogs the online relationships are based on the existing ideological values and views that reflect those of the science communication blogger. This context initiates and then reinforces a state of polarisation rather than developing shared values and views over time through regular and personal interactions.

6.2 Towards a new model of science communication

In considering the findings of my research for this thesis, I have been motivated on multiple occasions to attempt visualisations of new models of science communication. My first attempt after analysing the audit data was to illustrate the relationship between deficit, dialogue and participatory science communication as an overlapping spectrum, as shown in Figure 2. I used this diagram to explain the initial findings of my audit analysis at the 2014 Public Communication of Science and Technology conference in Brazil.

Figure 2. Spectrum model of science communication



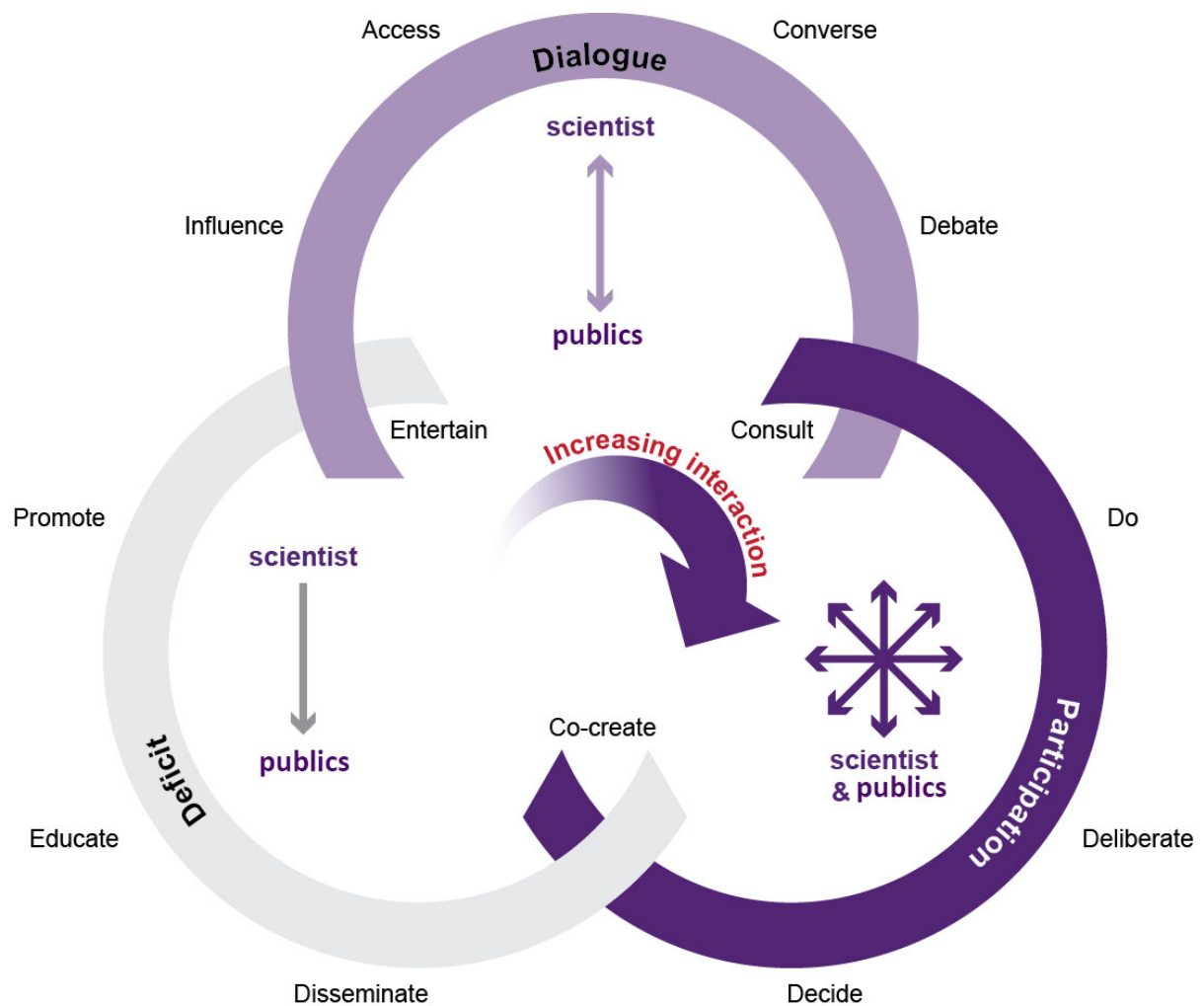
This model for science communication shows engagement happening from disseminating scientific information to the most advanced form of engagement, the co-creation of knowledge or tools. As science communication moves from dialogue to a participatory model, the level of interactivity between scientists and various publics increases.

This model incorporates a cross-over between the three traditional models of science communication, rather than a clear separation between them. For example, ‘entertaining’ people about science may create a dialogue or it may just be a very interesting one-way dissemination of knowledge. Likewise, consulting people about a scientific issue creates a dialogue, but may also be part of a more participatory and deliberative process. The model seeks to show there is not an abrupt division between the three forms of science communication. The three models of science communication are not mutually exclusive. However, this model is still evolutionary in nature showing a linear progression of science communication from dissemination to the more desired co-creation. It ignores the more detailed complexities of science communication revealed through my further analysis of audit data, the climate blogs and the Climate Champion Program. For example, it is quite likely that co-production of new knowledge will at some stage require a one-way dissemination of current knowledge from scientific experts to those with lay expertise. It is also likely to require the participating groups to consult with each other using various dialogue approaches. Thus, I developed a second model, as shown in Figure 3, which recognises that while the stated objectives of a science communication activities may align with one of the three science communication models, features of all three science communication models co-exist and complement each other in many science engagement activities. The rosette shape of

this second model seeks to emphasise this coexistence and avoid the notion that the three models are linear or sequential.

The rosette model shows the engagement between scientists and publics where interactivity increases from the one-way communication of the deficit model, to the two-way communication of the dialogue, to multiple participants interacting in many directions with multiple sources of information and knowledge. Both of my first two science communication models include the objectives that are likely to be driving the engagement, and which affect the style and nature of engagement activities, although such objectives are rarely explicitly articulated by practitioners (Powell & Colin, 2009). My first spectrum model (Figure 2) shows 10 communication objectives that may occur over the sequence from disseminating to co-creating, however my second rosette model (Figure 3) shows three additional objectives: to converse, debate or decide. These additional objectives emerged as I explored the data further, in particularly the audit and blog data. The objective 'to decide' emerged from initially analysing the audit data where respondents appeared to want to help various publics, including policy makers, make more informed decisions. The converse and debate objectives emerged from the conversations that people were having as commenters on the blogs. As already discussed, many of those involved in the blog dialogues appeared to be simply involved in conversing with like-minded people or debating those who entered the conversation with a different viewpoint.

Figure 3. The rosette model of science communication



Many of the objectives I use in the first two models have not commonly been included in the models described by scholars. For example, the objective to ‘promote’, which refers to activities (mostly one-way) whereby members of particular scientific communities seek to promote an area or field of science, a career in science or a scientific organisation or program. Another objective is to ‘entertain’, where the primary objective for the activity is to create a sense of fun or enjoyment in science, and hence a greater appreciation. Such activities are not necessarily motivated by a need to fill a deficit but by the desire to engage the senses of others; to evoke emotion. To ‘influence’ aims to change attitudes or create greater support for a particular aspect of

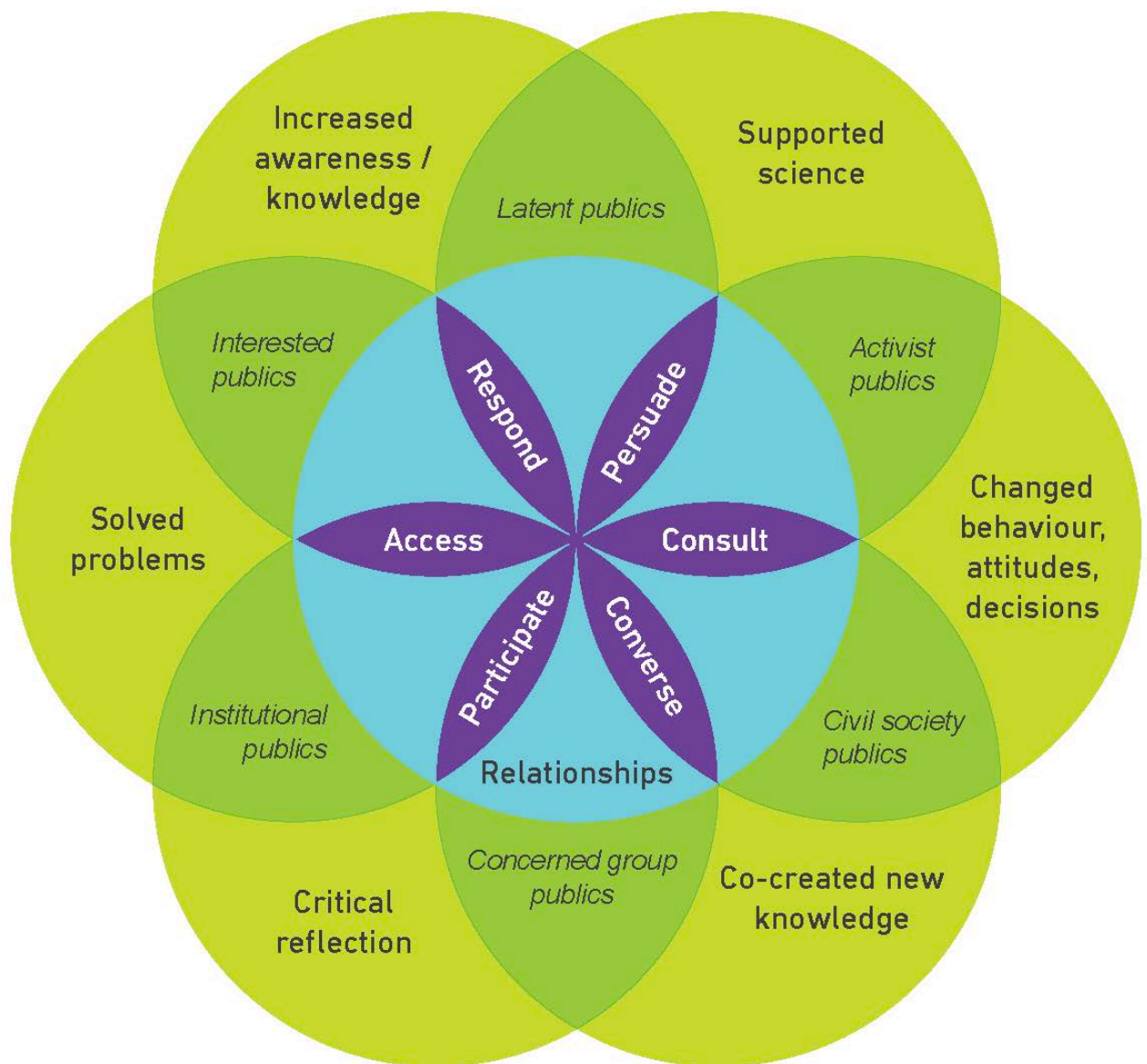
science. ‘Access’ aims to provide networks, access, support, and skills development. This objective is about capacity building so publics are more readily able to engage with science.

6.3 New nexus model of science communication

The participatory science communication research into the Climate Champion Program progressed my thinking beyond both of these first two models. In this research, a clear need emerged to demonstrate the foundational importance of positive relationships between scientists and various publics in delivering real outcomes from science communication. Hence, I developed the six-petal rosette science communication model, which I have called the ‘nexus model’ of science communication, as shown in Figure 4. This shape displays rotation and reflects the symmetries between the six intersecting lenses, which provides a useful metaphor for conveying the complexities of science communication and the ‘churn’ between science communication models.

This new model goes beyond the first two to focus on the key science communication actions (the inner six lenses shaded in purple) employed by scientists and science communicators to achieve their commonly-desired outcomes (the outer six circles shaded in mustard). The foundation for achieving all the outcomes is the central circle (shaded in blue) of positive relationships created between all the actors involved in the science communication process.

Figure 4. The nexus model of science communication



Different publics are imagined, created or recreated (Marres, 2007; Mohr & Ramen, 2012; Warner, 2002) through the processes and differing contexts of science communication. To demonstrate that publics can be created from the processes of science communication, this model also includes six different publics. The first is the ‘interested publics’, who are already engaged in science, and will seek out access to science through activities such as public lectures, science festivals and by searching for

online information. The second are ‘latent publics’ who appear to be disinterested but have the potential to be engaged in science through interactions with scientists, science communicators and other publics through entertaining events, relevant media articles, and so on. Once engaged, they can then become any of the other publics described in the model. The third are ‘activist publics’, also known as campaigning publics, who are organised to influence others and respond to scientific consultation around specific issues. ‘Civil society publics’ are those people who come together as a community to discuss and provide feedback about specific issues. ‘Concerned groups’ are involved in more long-term participatory science communication, where specific publics are involved with scientists to jointly produce new information, or to critically reflect on science.

Lastly, the relationships between scientists and specific publics can become so co-dependent that publics become part of the scientific ‘Institution’, whether this be a real institution or a project. Bucchi (2014) notes that publics and scientific experts involved in co-production of knowledge can become “inextricably intertwined... [as] a result of, and not a precondition for, the struggles, negotiations and alliances taking place in those configurations” (p. 72). This can happen through the establishment of influential citizen or stakeholder advisory committees or through an ongoing program involving a ‘concerned group’, where scientists participate with specific publics to critically reflect on science and its processes, as well as solve problems of mutual interest. For example, the Climate Champion Program started off as a ‘concerned group’, and then over time became institutionalised within the Managing Climate Variability program.

The nexus model does not seek to be inclusive of all types of publics, but rather theorises the dominant types of publics which may be within certain spaces and

contexts. For example, the ‘insular publics’ generated by polarised blogs might replace ‘civil society publics’, as they consult and converse with each other.

The outcomes depicted in this third model of ‘increased awareness and knowledge’, and ‘supported science’ (scientists and their institutions) are reminiscent of deficit-style objectives. Likewise, ‘changed behaviour, attitudes and decisions’ reflect the outcomes of theorised deficit and dialogue objectives. ‘Co-created new knowledge’, ‘critical reflection’, and ‘solved problems’ are the desired outcomes from the move towards more democratised science communication reflected in the theorised dialogue and participatory models. However, there is no representation of deficit, dialogue or participation in the nexus model; instead it emphasises the nexus between actions, relationships and publics that lead to outcomes. The nexus model also recognises that most desired outcomes from science communication involve a mix of objectives and activities across all three science communication models.

There is more work to do to refine the nexus model. For example, it does not represent how science communication changes with differing social, political and cultural contexts. For example, it would be interesting to investigate whether the model is representative or applicable to the contexts facing developing countries. I am also unclear if the model could or should reflect how science communication changes with the differing values of its participants. But, regardless of its limitations, this nexus model offers new perspectives on science communication, which can be further tested and developed by science communication scholars.

6.3 Implications for scholars

6.3.1 Recognising the coexistence of and dependence between science communication models

My research findings indicate that science communication scholars could better recognise the rich mix of objectives and activities undertaken by participants in science communication practice. Likewise, the co-existence of model characteristics in practice needs to be better recognised, tested and explored.

Of even more importance, is the finding that long-term participatory programs, like the CCP, can lead to relationships of trust between participants, which will make linear forms of communication more useful and effective. For science communication scholars still focused on the evolution of science communication from a deplored deficit to a desired end-point of deliberative participation, they would do well to consider the possibility that participatory communication may provide a necessary foundation for linear forms of communication, especially when the science is controversial. At the very least, scholars need to consider how participatory science communication activities could support and incorporate linear forms of science communication rather than urging practitioners to move beyond them.

6.3.2 Understanding the benefits of trusted relationships

My study of the CCP demonstrated that it is not necessary for such participatory programs to incorporate the predicted characteristic of co-production of new knowledge to achieve some useful outputs and changes from different parties participating together. Rather, it is relationships of trust that can lead to change. The benefits of developing trusted relationships in science communication about controversial topics like climate change is something that could be explored further by scholars with other case studies

and theoretical consideration. For example, as I have done with my latest science communication model (Figure 4), scholars would do well to consider how the role of science communicators in developing and supporting relationships between scientists and publics could be articulated within science communication models. This is an area where the theories found in humanities and cultural studies scholarship may prove of benefit.

6.4 Implications for practitioners

6.4.1 The need for more deliberative dialogic and participatory science engagement

The 2012 *Inspiring Australia* audit of Australian engagement activities indicates a paucity of sophisticated dialogic and participatory activities. While this data is now almost seven years old, there is little evidence that much is changing in Australia. An analysis of the 2018 National Science Week activities was presented by Isabelle Kingsley at the recent Australian Science Communication conference (November 2018). This analysis, using similar questions to those posed in the audit, found that 71% of National Science Week activities could be classified as being in the style of the deficit model.

My analysis of the audit indicated that most activities are reaching already interested publics, and there is a clear gap with the non-engaged. As already discussed, there is nothing wrong with responding to public demand for interesting science or promoting particular aspects of science, and indeed my findings indicate no reasons why these activities should not continue. But it is concerning so few activities appear to involve scientists participating with a variety of publics to tackle controversial issues of importance to society.

The few activities in the audit that address controversial science topics do not reflect the theorised characteristics of participatory science communication models with critical engagement of publics in the science, and more deliberative and inclusive approaches to problem solving and the creation of new knowledge. It is very possible that more of these participatory-style activities addressing controversial science in Australia are happening but were not recorded in the audit. However, indications are that far fewer engagement activities addressing controversial science are happening compared to non-controversial science, and that the engagement activities happening around non-controversial science topics are largely applying deficit or dialogue styles of communication rather than more participatory approaches. As I argue from the findings of this thesis, participatory approaches are likely necessary for deficit and dialogue objectives to be successful, especially when the science is controversial. These findings need to be tested further by analysing more participatory case studies.

The obvious explanation for the lack of more deliberative communication activities in Australia, especially longer-term interventions, is their cost, which points to a lack of political and organisational support for such activities. We held focus groups with science communicators prior to the audit where participants discussed the features of effective public engagement in science (Metcalf, Alford & Shore, 2012). Our analysis of the focus groups identified a clear desire from Australian science communicators to have more participatory style engagement activities, even if most of the engagement activities recorded in the audit failed to reflect such an approach. Focus group discussions focused on the timing of engagement, and the need to engage people throughout the science process. The second dominant theme identified was the importance of understanding the needs of various publics and appreciating the context, values and knowledge that publics bring to an engagement activity. Australian science

communicators clearly have a desire to enact more deliberative science communication, but they are not being supported or funded to do so.

Demonstrations of the power of longer-term participatory programs, like the Climate Champions program, to enact positive changes in response to problems through strengthening relationships between participants over time may help gain more support and funding of such programs in the future. Funding by government departments and scientific organisations for science communication activities currently tends to favour simpler deficit or dialogic activities, which are cheaper and easier to conduct. As the audit showed, organisations likely also find these easier to evaluate with quantitative metrics such as attendance numbers. My findings about the power of participatory-style communication for making deficit and dialogue-style communication more effective, especially on publicly-controversial topics, needs to be considered more fully by those institutions seeking to genuinely create positive societal changes.

6.4.2 Strategic application of science communication models

Applying elements of all three theorised science communication models to practice is likely to give a greater richness to the practice of science communication. This strategic approach to science communication recognises the benefits of each model as well as their limitations. Such an approach recognises that scientists and publics can play multiple roles; they can receive scientific knowledge; they can discuss and debate scientific knowledge; and they can determine and shape scientific knowledge.

Practically, the coexistence of the three models means that when publics are engaged with science, even with the most participative interventions, there is likely to be the need or even the demand from the actors at some stage to explain complex science in plain language to those involved (deficit model). However, the pejorative term of ‘deficit’ is not really appropriate for this style of communication. Rather than talking to

‘empty vessels’ (Irwin, 2006; Nisbet & Scheufele, 2009), science communicators are filling a demand or need from publics who are anything but ‘empty’ of knowledge. Perhaps a better term to use for this style of communication is ‘transmission’, which still reflects the one-way flow of information from scientists to publics.

Likewise, for any ‘interested group’ participating in an issue involving science, there will likely always be the need for a two-way dialogue, where different views are heard and acknowledged (dialogue), especially in the group’s set up phase. This will be an important pre-cursor to an ‘interested group’ fully participating with the scientists.

In considering the various predicted characteristics of each of the three models, as summarised in Table 15, I identified a series of questions that could assist science communicators to more strategically design their science communication (see last column of table). The three most important steps to consider when designing a public engagement activity are: (1) the objectives and hence the desired outcomes of the engagement; (2) who will be involved in the engagement; and (3) what is known about the perceptions, concerns and needs of the people being targeted. Once the answers to these questions are known, science communicators can better determine the desired relationship (see the centre circle in Figure 3) needed to achieve the desired outcomes.

Table 15. Comparing a summary of the characteristics predicted in science communication models with strategic science communication questions

<i>Characteristic</i>	<i>Model 1: Transmission (Deficit)</i>	<i>Model 2: Dialogue</i>	<i>Model 3: Participation</i>	<i>Science communication strategic questions</i>
Focus	Educate and inform publics	Create a dialogue that opens up science to publics and builds trust	Explore the direction, quality and need for social change	What is the overall focus of your science communication?
Outcomes	Increased awareness and knowledge about science Increased support for science	Understanding of publics Gain lay knowledge Changed behaviours, attitudes and decisions	Co-creation of knowledge and public policies Solutions to problems Critical reflection of science	What are the specific objectives of the communication? What are the desired outcomes?

<i>Characteristic</i>	<i>Model 1: Transmission (Deficit)</i>	<i>Model 2: Dialogue</i>	<i>Model 3: Participation</i>	<i>Science communication strategic questions</i>
Actors involved	Scientists, science communicators, publics	Scientists, science and government institutions, science communicators, publics	Many, depending on the scientific issue to be explored or the knowledge to be created	Who will be involved in the engagement? (try to be as specific as possible, don't just say 'publics') What do you understand about their perception, concerns and needs?
Communication style	One-way, top down	Two way	Many publics and approaches	What sort of communication style will work best given the people involved and your focus and objectives?
Relationship between actors	Scientists have control	Scientific and government institutions initiate the communication to consult or converse with the public	Equal and shared	What sorts of relationships are desired or possible amongst participants in the engagement? How can relationships be developed and supported?
Knowledge	Scientists have all the necessary knowledge	Scientists have the most important knowledge, but they also gain new knowledge from publics	There are multiple sources of knowledge and expertise of equal worth and validity	Who has the knowledge that is needed for achieving the activity's focus and outcomes? How is that knowledge best shared? How do the participants want to share / receive knowledge?
Acknowledgment of risk	Science portrayed as certain	Risks acknowledged as levels of uncertainty in scientific knowledge	Risk related to the social contexts and values	What are the science communication messages? Who will shape and interpret these messages? How can misinterpretation be avoided?
Example methods of communication	Lectures, presentations, publications, mass media, displays	Café Scientifiques consensus conferences, citizen juries, surveys, opinion polls, focus groups	Workshops, formal and informal meetings, on-site visits, citizen science	How do the publics want to be communicated with? What mix of methods will help

<i>Characteristic</i>	<i>Model 1: Transmission (Deficit)</i>	<i>Model 2: Dialogue</i>	<i>Model 3: Participation</i>	<i>Science communication strategic questions</i>
			initiatives, farmer field trials	build relationships between actors?
Timing of engagement	Usually at the end of science production after peer review	During the science and after peer review to discuss implications or policy options	Throughout, starting from the beginning with 'upstream engagement'	How important is it that publics shape the science, its products and communication? What does that mean about when engagement should happen in the science process?
Main challenges	Maintaining rationality, scientific independence and progress	Establishing broad social consensus / agreement Maintaining positive interactions	Viewing differences and disagreements as a societal resource	What are the risks involved that might stop the science communication from working? How might these be overcome?

Nisbet and Scheufele (2009) argue that deficit-style communication is unlikely to actually improve science literacy or understanding by the *wider* public and is most likely to only reach the minority who are *already enthusiastically engaged* in science. However, a combination of activities reflecting all science communication models, such as responding to their identified needs, providing access to the science, and using tools of persuasion may achieve desired outcomes, as postulated in the theorised model depicted in Figure 3.

Understanding the perceptions, concerns and needs of the people to be engaged is essential for ensuring the relevance of transmission-style activities, the opportunities for dialogue, and the desired involvement in participatory activities. Achieving such an understanding relies on participants in the science engagement process developing positive relationships of trust, as demonstrated throughout this thesis. Once some measure of trust has been achieved, greater understanding of target publics can be gained through a dialogic process, which can lead to:

Increasing democracy by promoting open and transparent decision-making; greater trust and confidence in the regulation of science and the decision taken; and that better decisions will have been taken (Jackson et al., 2005, p. 352).

Hence the process of strategic science communication, which incorporates at least some participatory forms of science communication that build relationships and shift the powerbase from solely residing with scientific institutions and scientists to one shared with publics, can in itself lead to the greater democratisation of science.

6.4.3 Using more deliberative forms of science communication

Despite the promise of blogs for more deliberative science communication when the public opinion about the science is polarised, there is a danger that using such tools will see communication become largely deficit in nature. Such tools are not particularly useful for the deliberation of controversial science such as that focused on climate change and are very unlikely to achieve objectives designed to create debate, reflection, attitudinal or behaviour changes, or the critical review of science. Based on the findings from the research in this thesis, science communication practitioners will not find blogs useful as a means of deliberatively engaging people in climate science; rather they serve to reinforce and validate the views of those participating. Instead, with controversial science debates a whole different set of strategies are required to create change, including reframing the issue to reduce polarisation, working from inside to directly influence decision-making, and working strategically with powerful outsider lobby groups who can advocate for change more successfully than scientific organisations who may not have the resources or will to engage in advocacy.

For practitioners interested in running more participatory science communication programs, the findings from the Climate Champion Program will be relevant. This program demonstrates the power of a long-term participation between

scientists and publics where resources are made available for developing trusted relationships through opportunities for mutually immersive experiences. When trusted relationships form, they make linear communication more likely to be effective for increasing the profile or awareness of the science, and in delivering consistent and clear messages that are less likely to be misinterpreted. Such trusted relationships also give publics more power to influence the design of research products and the communication of scientific research. The characteristics of the CCP that appeared to support its success as a participatory science communication program include:

- designing a deliberative communication strategy;
- initiating engagement between participants at the start of the program;
- providing as many opportunities as possible for formal and informal interactions;
- supporting participants to set their own objectives for the program, and agree on what activities they want;
- resourcing longer-term programs rather than short-term events; and
- ensuring science communicators take on a ‘boundary spanner’ (Jacobi et al., 2011) role to bring participants together and support their relationship-building.

Additional activities that would have possibly improved or added to the outcomes of the Climate Champion Program include involving other actors such as those from agribusiness, policymaking and rural health; and providing opportunities for more explicit discussion of participants’ values and their influence on relationship-building, co-learning, and decision making.

6.5 Limitations of research, and opportunities for further research

There are obvious limitations in the research I did on this thesis. I looked at 415 science engagement activities described by Australian science communicators at only one point in time—2012. I compared the comments over three time periods of two polar opposite climate blogs, which were set up and maintained by Australians but had an international reach. Finally, I looked at one long-term Australian participatory science communication program involving one set of publics with scientists – farmers. Moreover, this case study was focussed on climate change, which could possibly be different to other controversial issues, for example emerging technologies such as nanotechnology and synthetic biology. However, despite the limitations of geography and scope, my research, along with almost 30 years of practical science communication experience, does tell us some interesting things about science communication models and how they translate to practice.

This thesis also sets the foundation and identifies opportunities for further research focussed on examining the nexus between science communication theory and practice. The rich mix of objectives theorised by a wide range of scholars for each science communication model as identified in the literature review, along with those identified from the practice case studies could be further explored with relation to theorising further about science communication as well as by examining how such a diversity of possible objectives influences science communication practice.

It would also be interesting to research further whether the creation of insular publics, as shown with the climate change blogs I investigated, also happens with blogs on other controversial topics or with other social media mechanisms like Facebook and Twitter.

Another research opportunity is to further investigate the role and value of trusted relationships between the participants engaged in science communication. My investigation of the Climate Champion Program revealed how important trusted relationships were for the success of that program, which included more effectively applying deficit and dialogue style science communication. It would be interesting to further explore how trust is developed or not in other participatory programs and how long it takes for trust to develop between participants.

Given that my research was focussed on Australian practice, typical of many Western democracies, it would be useful to further test the coexistence of science communication models in practice in other countries and cultures. Likewise, it would be useful for practitioners if there were to be further research on how participatory science communication activities can support and incorporate linear forms of communication, as seemed to happen in the Climate Champion Program case study.

Another important element missing from theorisation about science communication models, is consideration of how science communication processes are influenced by the different values of the participants, something that Melanie McKenzie's PhD thesis (2014) focussed on, and which is largely missing from the scholarly literature as well as this thesis. The differing values of participants are likely to influence participatory science communication programs, and it would be useful to find out how and what this means for the practice of participatory science communication.

6.6 Concluding statement

When I started out on this PhD journey some seven years ago, I was firmly in 'deficit denial'. I argued that science communicators needed to be much more proactive in implementing more deliberative communication through dialogue and participatory

techniques, and they needed to renounce their ‘evil deficit’ ways. I was reminded of this starting point on my research journey recently while attending the national Australian Science Communicators’ conference (November 2018). Isabelle Kingsley, a speaker in my session, quoted from an article I wrote for *The Conversation* (Metcalf, 2013) on the national audit:

Science engagement in Australia is trapped by the 20th Century. It operates under an outdated model that aims to promote and celebrate science, rather than encouraging the public to participate in, and critically evaluate scientific endeavours.

As mentioned earlier in this chapter, Kingsley went on to say her research had similarly found that the deficit model was alive and well in Australia’s National Science Week engagement events. She presented the implications of this ‘negative’ situation for Australian science communication as problematic for meeting many of the objectives included in the participatory model. In some respects, she, and my pre-PhD self, have important points to make. Most science communication activities in Australia are still predominantly deficit in implementation, although the stated intent is more often than not striving towards more participatory engagement. This lack of deliberative science communication is unlikely to address the many challenges facing contemporary Australia. But, as I found out during my PhD research, establishing more deliberative objectives and activities is only part of the science communication story.

My PhD research findings revealed to me, both a practitioner and a scholar, the differing contexts, complexities and characteristics of science communication. Science communication happens in a multitude of directions within differing social, political and cultural motivations and contexts (Irwin, 2014). The strategic objectives set out by those initiating a science communication activity are not necessarily the objectives or

motivations of participants – and this can influence many of the facets of the communication.

My first realisation was that there is nothing inherently *wrong* with deficit-style science communication, especially if we talk about it as ‘transmission-style’, where information is transferred, often in response to publics’ demand, rather than addressing publics’ presumed deficit of knowledge with what it deemed by scientists to be necessary information. Such a transfer of information can meet the demands of interested publics, seek to educate people who need such knowledge for decision-making, and it can promote the importance and excitement of science to latent or interested publics (Broks, 2006). That in itself is enough to justify not throwing out the deficit, or rather ‘transmission’ model, of science communication.

Secondly, my reanalysis of the audit data after the publication of the report (Metcalf, Alford & Shore, 2012) shows that it is not possible to classify most activities as only deficit, dialogue or participation. Most science engagement activities, especially those with deficit or dialogue-style objectives, show characteristics that are a mix of those predicted for at least two of the models in terms of their objectives and the nature of the engagement between actors.

Most importantly, the participants in more deliberative participatory science communication activities demand the knowledge and discussions that are delivered through deficit and simple dialogue techniques, as evidenced by my study of the Climate Champion Program. Publics sometimes do want to know the latest scientific evidence, and scientists sometimes do want to know the social contexts of the publics as well as their perceptions, concerns and needs. And, as demonstrated by the findings in this thesis, it is through a participatory process where relationships of trust are developed that such deficit and dialogic techniques are most likely to be effective. I

conclude that participation needs deficit and dialogue techniques, but also enables such techniques to create real changes to the attitudes, behaviours and decision making of both publics and scientists.

Lastly, my research has empirically reinforced my belief in the crucial importance of enabling and nurturing quality relationships between scientists and publics. While such long-term participatory processes take time and can be costly, they provide the means for genuine participation and enhanced democratisation of science and its institutions. Positive relationships among scientists and publics have the power to create the change that society needs.

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Appendices

Appendix A—2012 Australian National Audit of Science Engagement

Activities online survey tool

Science engagement national audit

Inspiring Australia's National Audit of Science Engagement

As part of the Inspiring Australia aims, we want to create a database of science engagement activities in Australia, understand gaps and help with creating evaluation tools.

To do this, we want a snapshot of activities/programs taking place between January 2011 and June 2013. If your engagement activity has/is happening or is funded and planned for this time period, please fill in the survey.

****CLOSING DATE: SATURDAY 30 JUNE 2012****

We are only asking for information that is or will be publicly available, and not for your trade secrets!

You can enter three activities, then we ask one set of general questions. If you have more than three activities, you can then enter them (and skip the general questions if you already filled them out).

We are asking you about the following categories of information:

- an overview
- who is involved
- funding, support
- the activity in more depth
- evaluation.

By participating in the survey, you go into a draw to win a case of good-quality wine or a \$150 bookshop voucher.

You can enter more than one engagement activity into the survey, and will be prompted after completing the first engagement activity to enter another if you wish.

The survey should take you about 10-15 minutes per project, depending on how much you write!

If you would like more information about this survey, please contact Econnect Communication (07 3846 7111, admin@econnect.com.au, www.econnect.com.au).

By entering your data, you will receive the first report on all the data gathered.

Science engagement national audit

Overview of the activity

1. What's the name of this engagement activity?

2. Is there a website/webpage that describes the activity? Please give the URL below.

3. When did/will the activity start (month, year)?

4. When did/will it finish (month, year)?

5. What are you doing? We'd like a brief description of the actual activity.

6. What significant issues, needs or priorities is your activity addressing?

7. Please rank the outcomes your activity seeks.

	1 (high importance)	2	3	4	5 (low importance)
Inspire target groups and get them to value scientific endeavour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Attract increasing national and international interest in science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Critically engage target groups with key scientific issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Encourage young people to pursue scientific studies/careers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please specify your 'others', top to bottom.

Science engagement national audit

8. What does your activity focus on?

	major component of activity				not present in activity
Understanding of the natural and human-made world	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The nature of the scientific process or enterprise	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Societal and environmental impacts and implications from science and technology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal, community and societal values related to applications of science and technology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Institutional priority or public policy change related to science and technology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Science engagement national audit

Who is involved

1. From the groups below who you may be targeting with this activity, please estimate the number of people who are (or are expected to be) involved. If you are not targeting a specific group, leave that row blank.

	Up to 20	21-50	51-200	201-500	More than 500
Politicians	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Policymakers and advisers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Decision-makers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business leaders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous communities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
School-aged children (but not necessarily in schools)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Metropolitan communities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regional communities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Remote communities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
General public	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please specify who your 'others' were, top to bottom

2. Where are the group/s you are targeting (as identified in previous question) located? Give us specifics for each location, or leave the box blank if you're not targeting anyone there.

International (which countries?)	<input type="text"/>
National (which regions/areas?)	<input type="text"/>
State/territory (which ones?)	<input type="text"/>
Regional (which regions? e.g. Corangamite CMA in Vic; Kakadu NP in NT)	<input type="text"/>
Towns/suburbs (which ones?)	<input type="text"/>

Science engagement national audit

3. Who is involved in the activity? If you can, please let us know the specific names of the organisations/departments within the groups below which are relevant to you. If a group is not involved, leave the box blank.

Business/corporation	<input type="text"/>
Tertiary education facility e.g. university, TAFE, college	<input type="text"/>
State government e.g. Department of Environment	<input type="text"/>
Federal government e.g. Department of Finance	<input type="text"/>
Local government	<input type="text"/>
Non-government organisations	<input type="text"/>
Professional scientific associations/societies	<input type="text"/>
Government funded research agency e.g. CSIRO, AIMS	<input type="text"/>
Consultancy	<input type="text"/>
Media e.g. ABC Science Unit	<input type="text"/>
Cultural organisation e.g. museum, library, art gallery, science centre	<input type="text"/>
Other (please specify)	<input type="text"/>
Other (please specify)	<input type="text"/>
Other (please specify)	<input type="text"/>

4. Is there a main agency/organisation leading the activity? If so, please specify. Note: this is who is 'running' the activity, and it may be for a client; do not list the client here.

5. Please name the main funder of the activity.

6. Please name the secondary funder of the activity (leave blank if not relevant).

7. Please name the third funder of the activity (leave blank if not relevant).

8. Please name the fourth funder of the activity (leave blank if not relevant).

Science engagement national audit

1. What are the in-kind and/or cash contributions from funders as a per cent of overall project funds (approximately)?

	Cash % of project funding	In-kind % of project funding
[Q13]	<input type="text"/>	<input type="text"/>
[Q14]	<input type="text"/>	<input type="text"/>
[Q15]	<input type="text"/>	<input type="text"/>
[Q16]	<input type="text"/>	<input type="text"/>

Comments

2. Which major fields of science are involved in the activity? Tick all that apply.

- ☐ Mathematical sciences
- ☐ Physical sciences
- ☐ Chemical sciences
- ☐ Earth sciences
- ☐ Environmental sciences
- ☐ Biological sciences
- ☐ Agricultural and veterinary sciences
- ☐ Information and computing sciences
- ☐ Engineering
- ☐ Technology
- ☐ Medical and health sciences
- ☐ Social sciences

Science engagement national audit

Engagement activity in more depth

1. Can you describe the motivation for the activity? (e.g. saw others doing it, my organisation wanted me to, the research shows this is a good thing to do, we had some spare cash, it seemed like a good idea, etc.)

2. How are your target group/s involved in the activity?

	Not part of activity		Part of activity		Major component of activity
Learning from watching, listening, viewing lectures, media and/or exhibits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Asking questions of experts, interactive inquiry learning in activities/exhibits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consulting, sharing views and knowledge among/between participants and science experts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Deliberating with other participants and group problem-solving	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Producing recommendations or reports	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

3. What tools have you used to engage?

- | | | |
|--|---|--|
| <input type="checkbox"/> Social media | <input type="checkbox"/> Field day | <input type="checkbox"/> Link to network |
| <input type="checkbox"/> Traditional media | <input type="checkbox"/> Social event | <input type="checkbox"/> Link to education providers |
| <input type="checkbox"/> Art | <input type="checkbox"/> Exhibition | <input type="checkbox"/> Peer-to-peer communication |
| <input type="checkbox"/> Music | <input type="checkbox"/> Interactive exhibition | <input type="checkbox"/> Survey |
| <input type="checkbox"/> Website | <input type="checkbox"/> Newsletter/emails | <input type="checkbox"/> Questionnaire |
| <input type="checkbox"/> Face-to-face | <input type="checkbox"/> Formal paper | <input type="checkbox"/> Interview |
| <input type="checkbox"/> Phone | <input type="checkbox"/> Fact sheet | <input type="checkbox"/> Focus group |
| <input type="checkbox"/> Workshop | <input type="checkbox"/> Brochure | <input type="checkbox"/> Consultative meeting |
| <input type="checkbox"/> Seminar | <input type="checkbox"/> Briefing paper | |
| <input type="checkbox"/> Conference | <input type="checkbox"/> Establish network | |

Other (please specify)

Science engagement national audit

4. When in the science process is the engagement activity happening?

- ☐ to get support for funding of science before it happens
- ☐ to get target group involvement in shaping the science question
- ☐ to involve them in doing the science
- ☐ to get support for funding during the science
- ☐ the engagement is about ongoing science
- ☐ the engagement is about completed science

5. Who is involved in delivering the engagement activity? If you rank any 'others', please tell us who each group is in the comment box below (in order).

	1 (high involvement)	2	3	4	5 (low involvement)
Communication professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientists who did or are doing the research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other scientists not directly involved in the research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other specialists (e.g. graphic designer, artists, actors, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Managers (e.g. resources, business, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Interpretation specialists (e.g. museum curators, science centre education officers, rangers)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Volunteers (other than scientists)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (specify below)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (specify below)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (specify below)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Your 'other' groups, in order, top to bottom

Science engagement national audit

Evaluation

1. Did you have any evidence that your engagement activity was likely to work before starting it? If so, please describe.

2. How do you make sure of the credibility, currency and accuracy of the science involved in your engagement activity?

3. What kind of evaluation have you done or do you plan to do?

- ☐ None
- ☐ Informal
- ☐ In-house
- ☐ External
- ☐ Other

(please specify)

4. How are you evaluating/have evaluated/plan to evaluate the activity?

- ☐ Feedback forms
- ☐ Focus groups
- ☐ Surveys
- ☐ Pre-testing materials
- ☐ Media monitoring
- ☐ Web-traffic monitoring
- ☐ Interviews
- ☐ Other

(please specify)

5. If there was one thing that would tell you your engagement was successful, what would that be?

Science engagement national audit

1. What do you think are the critical areas where we need to improve the quantity or quality of science engagement in Australia? (Your answers to this question will not be linked to your case study or to your name.)

2. About you

Your name	<input type="text"/>
Your organisation	<input type="text"/>
Your position	<input type="text"/>
Your email	<input type="text"/>
Your role in the activity/ies	<input type="text"/>
Your postcode	<input type="text"/>
Your phone number	<input type="text"/>

3. May we list the following information publicly? All other demographic information will be private.

	Yes	No
Your name	<input type="radio"/>	<input type="radio"/>
Your organisation	<input type="radio"/>	<input type="radio"/>
Your position	<input type="radio"/>	<input type="radio"/>
Your email	<input type="radio"/>	<input type="radio"/>

If you answered no to any of these, is there someone else who may be willing to be listed instead? If so, name them below and give contact details.

4. Can we contact you if we want more information?

- ☐ Yes
- ☐ No

If not, is there someone else who may be willing to answer questions? If so, please name them below and give their contact details.

Science engagement national audit

5. Would you like to be in the draw for a random prize? (If you choose a prize preference, please make sure you've given us your name and phone/email above.) If you don't want to be in the draw, just leave this blank.

☐ Book voucher

☐ Red wine

☐ White wine

Appendix B—Promotional document



An Australian Government Initiative

Inspiring
AUSTRALIA

The biggest snapshot of science engagement in Australia

It's a picture as big as Australia. A flash of light illuminating how people are getting science out there. And it's the first time it's been done.

The picture shows everyone who is engaging people with any science, from anywhere, any organisation, even into the future—that's the goal.

Inspiring Australia wants to create a snapshot of all of the diverse science communication activities and programs going on between January 2011 and June 2013, and we need the help of anyone doing science engagement across the country.

People can help by filling out a [survey about the science engagement that they're a part of](#). We'll put the results into a visual national online database that anyone can explore. The database is part of a national audit that will help us all understand:

- who are Australia's players in science engagement—internationally, nationally, regionally and locally
- where and who is missing out on science engagement
- if and how Australians respond to science engagement activities
- how people can link their activities or ideas together
- how people are evaluating their engagement activities, or not
- how we can create better tools for evaluation
- the bigger picture of science engagement in Australia—with lots of opportunity for research.

The survey and database are being created in response to the Inspiring Australia Expert Working Group report [Developing an Evidence Base for Science Engagement](#). It's the first of a suite of projects tackling the report's recommendations.

As well as the survey, we will do personal interviews and a desktop review to make sure that we capture as many activities as possible.

The team comprises Jenni Metcalfe (Econnect Communication), Kristin Alford (Bridge8), and Jesse Shore and Kali Madden (Australian Science Communicators). Nancy Longnecker (UWA), Rod Lamberts (ANU) and Joan Leach (UQ) are advisors for the project. The data will help develop a national evaluation tool for science engagement activities—another initiative in response to the report's recommendations.

The audit will help science communicators to be seen as part of the big picture of science engagement in Australia and their standing with respect to the world. This Inspiring Australia initiative is supported by the Australian Government through the Department of Industry, Innovation, Science, Research & Tertiary Education in partnership with Econnect, Bridge8, ASC and UWA.



Appendix C—Climate Champion Program surveys with scientists and farmers

1. 2013 survey of scientists

1. In what sector is your research/work? eg. water, climate forecasts, app development
2. What state/region do you work in?
3. What organisation do you work for?
4. How many farmers did you interact with as part of your research?
5. When/how did you have contact with them? Pick all that are relevant.
 - Directly - I contacted them
 - Directly - they contacted me
 - Indirectly - through Econnect staff
 - Survey
 - Phone interview
 - Face to face
 - At a workshop
 - At a conference/seminar
6. Before you started interacting with them, how did you think the Climate Champion Program farmers would be able to assist your research?
7. How did you interact with them? e.g. did you want to know about what the farmer is doing on their farm; a pointer to where to get other information; requesting a presentation; or looking to involve the farmer in research?
8. Did your interactions with the Climate Champion farmers result in you changing anything about your research and its intended outcomes? If so, please explain.
9. Did you find that the contact with the Climate Champion farmer/s met your expectations? Was it a satisfying or disappointing experience? Why or why not?
10. Would you recommend liaising with Climate Champion Program farmers to other researchers working on similar projects to yours?
Yes
No
11. Do you have any suggestions to improve the program in the future?

2. 2016 End-of-Program survey of scientists

Your involvement with the Climate Champion Program

1. Please rate your involvement with the following Climate Champion Program activities from 1 (no involvement) to 5 (very high involvement):

- Presenting at Climate Champion workshops
- Discussing my research at Climate Champion workshops
- Requesting feedback to draft research tools or products from Climate Champions
- Asking Climate Champions to input into my research
- Responding to Climate Champion queries
- Inviting Climate Champions to participate / present at conferences or workshops
- Informal interactions with Climate Champion participants
- Other (Please describe)
- Other (please describe)

1. Please rate your involvement with the following Climate Champion Program activities from 1 (no involvement) to 5 (very high involvement)

2. How satisfied were you with your involvement in the program? Please rate from 1 (not at all) to 5 (very high)

3. Please explain * your answer to Q2

Communicating with other farmers about climate risk

4. An important objective of the Climate Champion Program was to support participants to communicate to other farmers in their regions and industries about climate risk. How well do you think the program achieved this? Rate from 1 (not at all) to 5 (very well)

5. How would you rate the overall program's ability to change farmer/ advisor attitudes about climate risk and management? Rate from 1 (none) to 5 (very high)

6. How would you rate the overall program's ability to change behaviours (e.g. on-farm practices; use of seasonal forecasting tools) about climate risk and management? Rate from 1 (none) to 5 (very high)

7. Was there one incident or event that stands out most in your mind that demonstrated change to farmers' attitudes or behaviours as a direct result of the program's activities? If so, please describe.

Your interaction with Climate Champions

8. How would you rate the quality of any feedback you received from Climate Champions? Rate from 1 (poor) to 5 (very high).

9. How willing do you think Climate Champions were to listen to your ideas? Rate from 1 (not at all) to 5 (very willing) Also allow a not applicable button.

10. How responsive do you think Climate Champions were to any questions you asked of them? Rate from 1 (not at all) to 5 (very responsive)

11. Did or do you do anything differently because of your interactions with Climate Champions? If so, please describe

12. Did any of the Climate Champions do anything differently because of your interactions with them? If

so, please describe

Overall views

13. What was the best single thing about the Climate Champion Program for you personally?
14. What do you believe was the best single thing about the Climate Champion Program for Australia?
15. Do you have any suggestions for how it could have been improved?
16. Your name: (optional)
17. Tick if you would like your responses NOT to be used in Jenni's PhD research

Not to be used

THANK YOU

3. 2016 End-of-Program survey of Climate Champion farmers

Your formal involvement

1. When did you join the program? Please tick * one answer only

Financial year 2009-2010

Financial year 2010-2011

Financial year 2011-2012

Financial year 2012-2013

Financial year 2013-2014

Financial year 2014-2015

Financial year 2015-2016

2. When did or will your formal involvement in the program end?

June 30, 2013

By June 30, 2016

Communication Skills

3. One of the objectives of the program was to help develop your skills to communicate with other farmers and industry. How significant was the program in improving your communication skills? Rate from 1 (none) to 5 (very significant) your improvement in the following communication skills as a result of the Climate Champion Program.

Communicating with other farmers about climate risk

4. Another objective was to support you to communicate to other farmers in your region and industry. How helpful was the program in supporting your communication with other farmers? Rate from 1 (no help) to 5 (very helpful)

5. How would you rate your own level of activity in communicating about climate risk management to other farmers as a result of your involvement in the Climate Champion Program? Rate from 1 (no change) to 5 (much higher activity)

6. How much do you think you were able to increase other farmers' use of climate risk knowledge or tools? Rate from 1 (none) to 5 (very high)

7. How would you rate the overall program's ability to change attitudes about climate risk and management? Rate from 1 (none) to 5 (very high)

8. How would you rate the overall program's ability to change behaviours (e.g. on-farm practices; use of seasonal forecasting tools) about climate risk and management? Rate from 1 (none) to 5 (very high)

9. Was there one incident or event that stands out most in your mind that demonstrated change to farmers' attitudes or behaviours as a direct result of your or the program's activities? If so, please describe.

Communicating with researchers

10. How much did you interact with climate researchers during the program? Rate from 1 (none) to 5 (Very High)

11. How active were you in providing feedback to researchers about their draft tools or products? Rate from 1 (not active at all) to 5 (very high)

12. Were there enough opportunities to interact with researchers? * Tick one box.

Too little

Just right

Too much

13. How would you rate the quality of information you received from researchers? Rate from 1 (poor) to 5 (very high)

14. How would you rate the presentation style of researchers at Climate Champion workshops? Rate from 1 (poor) to 5 (very high)

15. How willing do you think researchers were to listen to your ideas? Rate from 1 (not at all) to 5 (very willing)

16. How responsive do you think researchers were to the questions you asked? Rate from 1 (not at all) to 5 (very responsive)

17. Did you do anything differently because of your interactions with researchers? If so, please describe.

18. Did the researchers do anything differently because of your interactions with them? If so, please describe.

Overall View

19. What was the best single thing about the Climate Champion Program for you personally?

20. What do you believe was the best single thing about the Climate Champion Program for Australia?

21. Do you have any suggestions for how it could * have been improved?

22. Your name: (optional)

23. Tick if you would like your responses NOT to be used in Jenni's PhD research

Not to be used

THANK YOU